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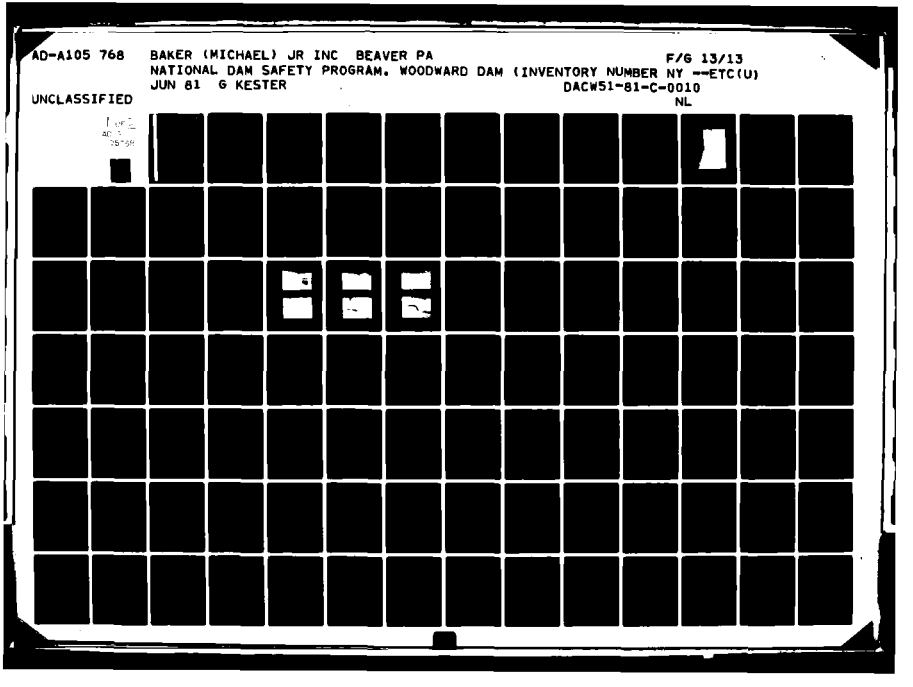

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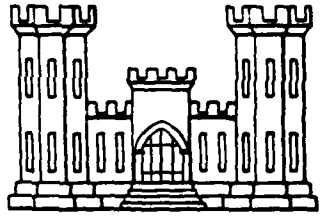
LOWER HUDSON RIVER BASIN

WOODWARD DAM

LEVEL II

ORANGE COUNTY, NEW YORK
INVENTORY NO. 507

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM



NEW YORK DISTRICT CORPS OF ENGINEERS

JUNE 1981

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Dam Safety
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Woodward Dam
Orange County
Lower Hudson River Basin

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report provides information and analysis on the physical condition of the dam as of the report date. Information and analysis are based on visual inspection of the dam by the performing organization.

Examination of available documents and a visual inspection of the dam and appurtenant structures did not reveal conditions which constitute an immediate hazard to human life or property.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Using the Corps of Engineers' screening criteria, it has been determined that the dam would be overtopped for all storms exceeding approximately 60 percent of the Probable Maximum Flood (PMF). Therefore, the spillway is adjudged "inadequate."

No signs of instability were noted in the embankment; therefore, no stability analysis will be required.

Current inspection and maintenance procedures by the owner are adequate but need to be documented. Monitoring of the reservoir levels should be expanded to include readings during peak flow periods.

PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I Investigations. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D.C. 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I Investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through frequent inspections can unsafe conditions be detected and only through continued care and maintenance can these conditions be prevented or corrected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the Spillway Test flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. Because of the magnitude and rarity of such a storm event, a finding that a spillway will not pass the test flood should not be interpreted as necessarily posing a highly inadequate condition. The test flood provides a measure of relative spillway capacity and serves as an aide in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
WOODWARD DAM
I.D. No. NY 507
DEC DAM No. 179A-562 LOWER HUDSON RIVER BASIN
ORANGE COUNTY, NEW YORK

TABLE OF CONTENTS

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

Name of Dam:	Woodward Dam (I.D. NY 507)
State:	New York
County:	Orange
Stream:	Little Shawangunk Kill
Dates of Inspection:	10 January 1981 9 March 1981

ASSESSMENT

Examination of available documents and a visual inspection of the dam and appurtenant structures did not reveal conditions which constitute an immediate hazard to human life or property.

Using the Corps of Engineers' screening criteria, it has been determined that the dam would be overtopped for all storms exceeding approximately 60 percent of the Probable Maximum Flood (PMF). Therefore, the spillway is adjudged "inadequate."

No signs of instability were noted in the embankment; therefore, no stability analysis will be required.

Current inspection and maintenance procedures by the owner are adequate but need to be documented. Monitoring of the reservoir levels should be expanded to include readings during peak flow periods.

The following remedial measures must be completed within one year.

Woodward Dam:

1. All low areas on the crest of the dam must be filled to the average crest elevation, compacted, and seeded.

2. Riprap must be placed on the upstream face of the dam above normal pool level.

3. The seep and wet areas at the toe of the dam must be monitored at regular intervals and during

periods of high reservoir levels for turbidity and increase in flow, which may indicate potential for the piping of embankment material.

4. The eroded areas at the downstream end of the spillway discharge channel must be repaired and protected.

5. All trees and brush must be cut off at ground level on the downstream toe, upstream slope, and spillway discharge channel. The root systems of all trees with a trunk diameter greater than 3 inches must be removed from the downstream toe of the dam. All resultant areas of erosion and cavities must be filled, graded, compacted, and seeded.

6. The animal burrow at the toe of the dam must be filled, compacted, and seeded.

7. Spalled areas in the concrete of the gate house and concrete weir must be repaired.

8. A staff gage must be installed to monitor reservoir levels above normal pool.

Greenleaf Dam:

1. The seep at the toe of the dam must be monitored at regular intervals and during periods of high reservoir levels for turbidity and increase in flow, which may indicate potential for the piping of embankment material.

2. Riprap must be placed on the upstream face of the dam above normal pool level.

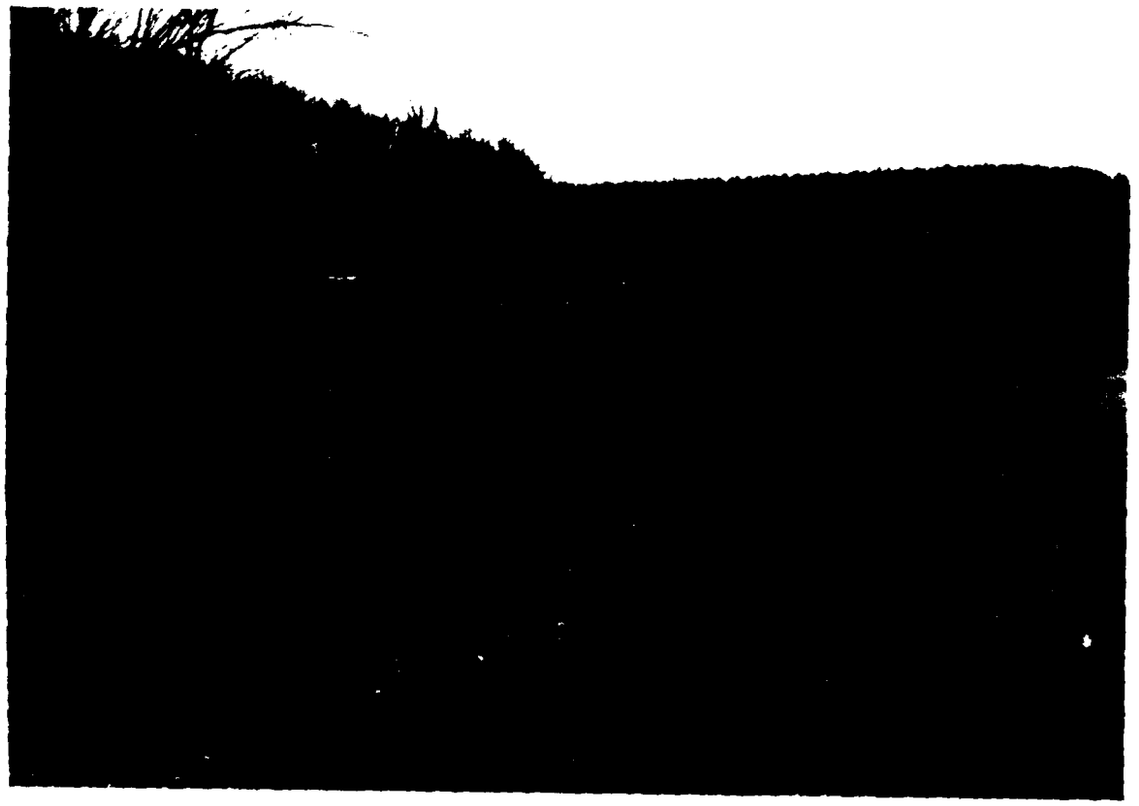
3. All trees and brush must be cut off at ground level on the downstream toe of the dam. The root systems of all trees with a trunk diameter greater than 3 inches are to be removed. All resultant areas of erosion and cavities must be filled, graded, compacted, and seeded.

4. The animal burrow and depression on the downstream side of the dam must be filled, graded, compacted, and seeded.

SUBMITTED: _____
Granville Kester, Jr., P.E.
Vice President
MICHAEL BAKER, JR. of New York, INC.

APPROVED: _____
Colonel W.M. Smith, Jr.
New York District Engineer

DATE: 30 JUN 1981



Overall View of Dam
Woodward Dam
I.D. No. NY 507
9 March 1981

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
WOODWARD DAM
I.D. No. NY 507
DEC DAM No. 179A-562
LOWER HUDSON RIVER BASIN
ORANGE COUNTY, NEW YORK

SECTION 1: PROJECT INFORMATION

1.1 GENERAL

a. Authority - The Phase I Inspection reported herein was authorized by the Department of the Army, New York District, Corps of Engineers, to fulfill the requirements of the National Dam Inspection Act, Public Law 92-367.

b. Purpose of Inspection - This inspection was conducted to evaluate the existing conditions of the dam, to identify deficiencies and hazardous conditions, to determine if these deficiencies constitute hazards to life and property, and to recommend remedial measures where required.

1.2 DESCRIPTION OF PROJECT

a. Description of Dam and Appurtenances - Shawangunk Lake is formed by Woodward Dam and Greenleaf Dam. Woodward Dam is an earthfill dam with a height of 29.7 feet, measured from the minimum top of dam to the toe of the dam, and a total length of 463 feet. The embankment has a crest width of 9 feet. The side slope of the upstream face is 1V:2.4H (Vertical to Horizontal) and the side slope of the downstream face is 1V:2.2H. The upstream face of the embankment is protected by riprap up to normal pool level. The original plans show a masonry core wall, but test pits dug by the owner reportedly show no evidence of this core wall. The reservoir is used as a water supply for the City of Middletown, New York.

The spillway is 50 feet from the right abutment and 18 feet upstream from the crest of the dam. The crest of the weir is 18.7 feet long (perpendicular to the direction of flow). The breadth of the weir (parallel to the direction of flow) is 1.1 feet. Flow over the spillway falls 2.7 feet to the discharge channel.

The discharge channel extends approximately 300 feet downstream from the crest of the weir. The portion of the channel extending downstream from the weir to the downstream side of the access bridge on the crest of the dam is rock-lined with stone side walls. Downstream from the access bridge, the discharge channel is a trapezoidal, rock-lined channel. A large number of trees are growing in this section of the channel.

The outlet from the reservoir consists of a 20-inch water supply line which gravity feeds to Monhegan Lake, 1 mile northeast of Shawangunk Lake. The upper level intake for the 20-inch water supply line is 11.6 feet below normal pool level, and the lower level intake is 26 feet below normal pool level. Both intake pipes (each 20-inch) are controlled by valves housed in a building on the upstream face of the dam. The plans show an 8-inch drain from the valve house to the downstream face of the dam, but this drain outlet could not be located.

Greenleaf Dam is an earthfill dam with a height of 27.9 feet, measured from the minimum top of dam to the toe of the dam, and a total length of 281 feet. The embankment has a crest width of 14.5 feet. The side slopes of the upstream and downstream faces are both 1V:2H. The upstream face of the embankment is protected by riprap up to normal pool level. Greenleaf Dam has no spillway or functioning outlet pipes.

b. Location - Woodward Dam, on Little Shawangunk Kill, is 1 mile east of Mount Hope, New York. The reservoir and dam are in Orange County, New York. The coordinates of the dam are N 41° 27.0' and W 74° 29.7'. Woodward and Greenleaf Dams can be found on the Middletown and Otisville, New York, USGS 7.5 minute topographic quadrangles.

c. Size Classification - The height of Woodward Dam is 29.7 feet and the reservoir storage capacity at the top of dam, elevation 769.7 feet M.S.L. (Mean Sea Level) is 1,633 acre-feet. Therefore, the dam is in the "intermediate" size category as defined by the Recommended Guidelines for Safety Inspections of Dams.

d. Hazard Classification - Mapes Road and one home are located 3200 feet downstream from Woodward Dam. There are also three other areas downstream where the stream passes under roadways and through residential developments (see Location Plan in Appendix E). Economic damage to the roads and residential areas is likely if the dam were to fail. The possibility of excessive economic damage places Woodward Dam in the "high" hazard category as defined by the Recommended Guidelines for Safety Inspection of Dams.

e. Ownership - The dams and reservoir are owned and operated by the City of Middletown, 16 James Street, Middletown, New York 10940. The contact person is Mr. Bill Johnson (Telephone 914-343-3169).

f. Purpose of the Dam - The dams and reservoir are used for water supply.

g. Design and Construction History - According to available records, the dams were originally built about 1901. The Woodward Dam was designed by W.R. Hill, consulting engineer and D.R. Lee, resident engineer. The contractor is unknown. A permit was issued to the City of Middletown to raise the dam 2.5 feet in July 1925. Plans were made for raising Woodward and Greenleaf Dams 10 feet in 1946-1947, but these plans were never implemented.

h. Normal Operating Procedures - The Shawangunk reservoir continuously feeds Monhegan Lake through a gravity-fed 20-inch pipe. The reservoir level is normally kept at the spillway crest. The dam and spillway are visually inspected daily, and weekly records are kept on the reservoir level. The valve for the 20-inch pipe is normally open and is periodically operated to check its condition.

1.3 PERTINENT DATA

a. Drainage Area (square miles) - 1.50

b. Discharge at Dam cubic feet per second (c.f.s.) -

Spillway Capacity (at Pool Elevation 769.7 Feet M.S.L.)* -	532.0
Reservoir Drain at Normal Pool	6.0

*All elevations are referenced to the spillway crest, elevation 767.0 feet M.S.L., as shown on the plans supplied by the owner.

c. Elevations (Feet above M.S.L.) -

Average Top of Dam	771.7
Minimum Top of Dam	769.7
Normal Pool (Spillway Crest)	767.0
Streambed at Toe of Dam	740.0

d. Reservoir Surface Area (Acres) -

Top of Dam (Minimum)	125.4
Spillway Crest	100.7

e. Reservoir Storage Capacity (Acre-Feet) -

Top of Dam (Minimum)	1633.0
Spillway Crest	1332.0

f. Dam -

Type:			Earth
Length (Feet)			463.0
Height (Feet)			29.7
Top Width (Feet) -	Design		20.0
	Field		9.0
Side Slopes - Upstream	-	Design	1V:2H
		Field	1V:2.4H
Downstream	-	Design	1V:2H
		Field	1V:2.2H

g. Spillway -

Type: Broad-crested concrete weir	
Length of Crest Perpendicular to Direction of Flow (Feet)	18.7
Width of Crest Parallel to Direction of Flow (Feet)	1.1
Crest Elevation (Feet M.S.L.)	767.0

h. Reservoir Drain -

Type: Gravity fed 20-inch water supply line to Monhegan Lake.
Control: Manual control valves in the gate house on the crest of the dam. The valves are normally open.

SECTION 2: ENGINEERING DATA

2.1 GEOLOGY

The Woodward and Greenleaf Dams, forming Shawangunk Reservoir, are located in the southern end of the "Hudson-Mohawk Lowlands" physiographic province of New York State. Most of this province is characterized by low elevation and relief due to the erosion of outcropping weak rocks. Bedrock occurring in the immediate vicinity of the dam, as indicated on the Geologic Map of New York (J.G. Broughton and others, 1970), consists of moderately to intensely folded shales and graywacke of the Austin Glen Formation, Trenton Group (Middle Ordovician). Tabular blocks of silt shale and fine grained sandstone were noted on both abutment slopes during the visual inspection. No major faults are reported in the vicinity of the dam. This entire area has been glaciated.

2.2 SUBSURFACE INVESTIGATION

Original subsurface information for Woodward Dam could not be located during this inspection. However, visual observation indicates that the area appears to be covered in part by glacial debris in the form of silt and fine sand.

According to the available soils report (preliminary) for Orange County, prepared by the USDA Soil Conservation Service, local foundation and abutment materials for the dam consist of the following soils:

Left Side: Arnot Rock Outcrop Association Soils - These soils are medium textured, well drained materials formed in glacial till derived from red shale and gray sandstone. Bedrock occupies from 50 to 90 percent of the mapped areas containing these soils. Soil thickness is approximately 1 to 1-1/2 feet. Depth to seasonal high water table is approximately 2+ feet.

Right Side: Bath Silt Loam - These soils are medium textured, well drained, yellowish brown, strongly to medium acid materials with a very firm fragipan that developed in deep glacial till derived from slates, shales, and sandstone mainly. Bath soils have approximately 2 to 2-1/2

feet of moderately permeable gravelly loam over 1-1/2 to 4 feet of slowly permeable, very firm gravelly silt loam. Depth to seasonal high water table is approximately 4+ feet.

2.3 DAM AND APPURTENANT STRUCTURES

Woodward and Greenleaf dams are earthen embankments built around 1901 by the City of Middletown for water supply purposes. The impoundment formed, Shawangunk Reservoir, is used in conjunction with the neighboring Kinch, Monhegan, and Highland eservoirs. Plans were formulated in 1946-1947 for ' .ising the Woodward and Greenleaf Dams to increase the storage area in Shawangunk Reservoir, but these plans were never implemented (Plate 5).

The appurtenant structures for operation of the reservoir are mainly located at Woodward Dam. A gate house on the upstream side of the dam houses two 20-inch cast iron intake pipes and the respective control valves. A 20-inch water supply pipe leads from the gate house to Monhegan Lake. An 8-inch blow-off pipe reportedly leads from the gate house to just downstream of the dam. However, the outlet of the blow-off pipe was not observed during the visual inspection (a seep was observed at the toe of the dam that is probably related to this outlet). Woodward Dam has a spillway located 50 feet to the left of the right abutment. The spillway contains a concrete weir 18.7 feet long which is offset 18 feet upstream of the crest of the dam. The crest of the weir lies 2.7 feet below the minimum embankment elevation. The discharge channel between the weir and just beyond the crest of the dam is protected by stone wing walls.

2.4 CONSTRUCTION RECORDS

Construction records are not available. General design plans were available for review as part of these investigations. These plans are included in Appendix E.

2.5 OPERATION RECORDS

Weekly observations of reservoir water levels are kept by a watchman for the City of Middletown. The watchman visually inspects Woodward Dam daily. The valves are reportedly operated periodically. Formal records of the inspections or operation of valves are not kept.

2.6 EVALUATION OF DATA

The background information collected during this investigation was obtained primarily from files of the New York State Department of Environmental Conservation. Supplementary information was acquired through conversations with Mr. Bill Johnson, representing the City of Middletown. The available data are considered adequate and reliable for Phase I Inspection purposes.

SECTION 3: VISUAL INSPECTION

3.1 FINDINGS

a. General - The inspection was performed on 10 January 1981. The weather was sunny and the temperature was 20° Fahrenheit. There was 4 to 6 inches of snow on the dam. The water surface was 13.6 feet below the spillway crest. This low reservoir level was attributed to an unusually low amount of precipitation occurring in the watershed prior to the inspection. Deficiencies found during the inspection will require remedial treatment. A Field Sketch of conditions found during the inspection is included in Appendix E. The complete Visual Inspection Checklist is presented as Appendix B. Because there was a snow cover on the dam during the initial inspection, a follow-up inspection was carried out on 9 March 1981.

b. Spillway - The spillway at Woodward Dam is 50 feet from the right abutment and 18 feet upstream from the crest of the dam. The spillway is a low, broad-crested, concrete weir with masonry training walls. The masonry training walls are placed stone with many voids and extend to the downstream side of the wood deck bridge, across the discharge channel at the crest of the dam. The right masonry training wall is collapsing under the bridge. The concrete weir has relatively major spalling on the downstream face. Greenleaf Dam has no spillway.

c. Embankment - No evidence of sloughing or subsidence was observed on the upstream or downstream slopes of the embankment at Woodward Dam.

The following is a list of deficiencies observed during the visual inspection of the embankment at Woodward Dam:

1. Minor erosion (riprap displacement) at normal pool level on the upstream face of the dam.

2. Minor low areas along the crest of the dam near the gate house.

3. A small amount of brush growing on the upstream slope of the dam.

4. Trees and brush growing on the downstream face and toe of the dam. There are six trees

24 inches in diameter and one tree 14 inches in diameter.

5. Minor seepage at the toe of the dam at Station 2+30. The estimated flow rate of the seep is 0.5 gallons per minute (g.p.m.). This could be from the 8-inch outlet pipe that could not be located during the visual inspection.

A wet area (10 square feet) was observed at Station 2+70 at the toe of the dam. The flow rate or source of this moisture could not be determined.

No evidence of sloughing or subsidence was observed on the upstream or downstream slopes of the embankment at Greenleaf Dam.

The following is a list of deficiencies observed at Greenleaf Dam during the visual inspection of the embankment:

1. Minor erosion (riprap displacement) at normal pool level on the upstream face of the dam.

2. Trees and brush growing on the downstream face and toe of the dam. There are two trees 24 inches in diameter.

d. 9 March 1981 Inspection - The reservoir level was approximately 4 feet higher during the second inspection than the initial inspection.

The only additional observation made at Woodward Dam was that there is an animal burrow in the downstream toe of the embankment at approximately the center of the embankment.

Several additional problems were observed at Greenleaf Dam, the dam which, along with Woodward Dam, forms Shawangunk Lake. These were: (1) an animal burrow in the downstream toe of the dam approximately 50 feet from the right abutment, (2) a wet area covering approximately 10 square feet at the downstream toe of the dam near the buried outlet for the abandoned outlet works; and (3) a small depression on the downstream face of the embankment slightly to the right of the center of the dam and approximately half-way down the downstream face. There was no measurable flow from the wet area and it could not be determined if the wet area resulted from seepage through the embankment, poor surface drainage, or seepage through the abandoned outlet works.

e. Outlet Works - A 20-inch pipe, 19,500 feet long, runs from the reservoir at Woodward Dam to Monhegan Lake. A gate valve on the upstream side is used to control the gravity flow to Monhegan Lake. The outlet for an 8-inch drain for the gate house as shown on the original plans could not be located at the time of inspection.

The gate house is a 14-foot by 28-foot brick structure on the upstream face of Woodward Dam. Spalled areas on the gate house foundation have been recently patched, but the patches are deteriorating.

Greenleaf Dam has no operating outlet works. An abandoned valve pit is on the crest near the center of the dam.

f. Downstream Channel - The discharge channel downstream from the Woodward Dam spillway has a mild slope with rocks, trees, and local accumulations of debris in the channel. At the downstream end of the discharge channel there is severe erosion of the channel banks.

One house and Mapes Road are located 3200 feet downstream from the dam.

g. Reservoir - The reservoir slopes are moderate with large wooded areas. There were no signs of slope instability and sedimentation is only a minor problem. At the time of inspection, some minor sedimentation was being removed from the reservoir.

3.2 EVALUATION

The visual inspection of Woodward Dam revealed several deficiencies in this structure. The following items were noted:

1. Minor low areas along the crest of the dam near the gate house.

2. Minor erosion (riprap displacement) at normal pool level on the upstream face of the dam.

3. Minor seepage at the toe of the dam at Station 2+30. The estimated flow rate of the seep is 0.5 gallons per minute (g.p.m.). This could be from the 8-inch outlet pipe that could not be located during the visual inspection.

4. A wet area (10 square feet) at Station 2+70 at the toe of the dam. The flow rate or source of this moisture could not be determined.

5. Severe erosion of the channel banks exists at the downstream end of the discharge channel.

6. Trees and brush growing on the downstream face and toe of the dam. There are six trees 24 inches in diameter and one tree 14 inches in diameter.

7. Trees growing in the spillway discharge channel.

8. A small amount of brush growing on the upstream slope of the dam.

9. An animal burrow at the downstream toe of the dam at approximately the center of the embankment.

10. Spalled areas on the concrete of the gate house.

The visual inspection of Greenleaf Dam revealed several deficiencies in this structure. The following items were noted:

1. A wet area at the downstream toe of the dam near the buried outlet for the abandoned outlet works.

2. Minor erosion (riprap displacement) at normal pool level on the upstream face of the dam.

3. Trees and brush growing on the downstream face and toe of the dam. There are two trees 24 inches in diameter.

4. A small depression on the downstream face of the embankment slightly to the right of the center of the dam and approximately half-way down the downstream face.

5. An animal burrow in the downstream toe of the dam approximately 50 feet from the right abutment.

SECTION 4: OPERATION AND MAINTENANCE PROCEDURES

4.1 PROCEDURES

There are no formal operating procedures. The reservoir continuously feeds Monhegan Lake through a gravity feed 20-inch pipe. The reservoir is normally kept at the spillway crest, but at the time of the inspection, the reservoir was 13.6 feet below the spillway crest because of a water shortage in the area.

4.2 MAINTENANCE OF THE DAM

Maintenance of Woodward Dam is the responsibility of the City of Middletown. The watchman visually inspects Woodward Dam daily and weekly records are maintained on the reservoir level. The grass is mowed and some of the trees are removed each year. The valves for the water supply line are operated periodically.

4.3 WARNING SYSTEM

At the time of the inspection, there was no warning system or emergency action plan in operation.

4.4 EVALUATION

Past maintenance of the dam and operating facilities appears to have been adequate, but, except for the water level measurements, the past activities have not been documented. A checklist should be compiled by the owner's representative to document the findings made during the periodic inspections and the maintenance items completed. A warning system and emergency action plan should be developed and put into operation.

SECTION 5: HYDRAULIC/HYDROLOGIC DATA

5.1 DRAINAGE AREA CHARACTERISTICS

Delineation of the watershed of Woodward Dam was made using the USGS quadrangles for Middletown and Otisville, New York. The drainage basin consists of moderate slopes which are well covered by forests and ground vegetation. Some storage exists in Highland Lake which is upstream from Shawangunk Lake, formed by Woodward Dam and Greenleaf Dam. A small amount of residential development exists in the drainage area. The total drainage area controlled by the dam is 1.50 square miles.

5.2 ANALYSIS CRITERIA

A hydrologic analysis of the watershed and hydraulic analysis of dam was conducted using the U.S. Army Corps of Engineers' Flood Hydrograph Package HEC-1 DB computer program (Reference 12, Appendix D). The unit hydrograph was defined using the Snyder Unit Hydrograph Method. Estimates of Snyder hydrograph coefficients were based upon average coefficients from the Hydrologic Flood Routing Model for Lower Hudson River Basin (Reference 16, Appendix D). Precipitation data was taken from Hydrometeorological Report No. 33 (Reference 8, Appendix D). Rainfall losses were estimated at an initial loss of 1.0 inch and a constant loss rate of 0.1 inch per hour thereafter. The hydraulic capacity of the dam, reservoir, and spillway was determined by incorporating the Modified Puls Routing Method. All flood routings were begun with the reservoir at normal pool level. Outlet discharge capacity was computed by hand. The Probable Maximum Flood (PMF) and 1/2 Probable Maximum Flood (1/2 PMF) were developed and routed through the reservoir.

The runoff hydrograph was routed through Highland Lake Dam and combined with the runoff hydrograph for Shawangunk Lake, then routed through Woodward Dam.

5.3 SPILLWAY CAPACITY

The spillway capacity at the minimum top of dam is 532 c.f.s. There is no auxiliary or emergency spillway at Woodward Dam.

5.4 RESERVOIR CAPACITY

The storage capacity of Shawangunk Lake at normal pool is 1332 acre-feet. The storage capacity of the reservoir at the minimum top of dam is 1633 acre-feet. Therefore, flood control storage of the reservoir between the spillway crest and top of dam is 301 acre-feet. This volume represents a total of 1.88 inches of runoff from the watershed.

5.5 FLOODS OF RECORD

No information concerning the effects of significant floods on the dam is available.

5.6 OVERTOPPING POTENTIAL

The maximum capacity of the spillway is 532 c.f.s. before overtopping would occur. The peak outflows of the PMF and 1/2 PMF are 1084 c.f.s. and 422 c.f.s., respectively. Therefore, the spillway is capable of passing 60 percent of the PMF before overtopping would occur.

5.7 RESERVOIR EMPTYING POTENTIAL

The reservoir can only be drawn down by the 20-inch, 19,500 foot long, gravity fed water supply line from Woodward Dam to Monhagen Lake. Neglecting inflow, the reservoir can be drawn down from normal pool in approximately 113 days. This is equivalent to an approximate drawdown rate of 0.3 feet per day, based on the hydraulic height measured from normal pool divided by the time to dewater the reservoir.

5.8 EVALUATION

Woodward Dam is an "intermediate" size - "high" hazard dam requiring the spillway to pass a flood in the range of the 1/2 PMF to PMF. The PMF and 1/2 PMF were routed through the watershed and dam. It was determined that the spillway is capable of passing 60 percent of the PMF before overtopping the dam. The spillway is, therefore, judged to be "inadequate."

Conclusions pertain to present conditions and the effect of future development on the hydrology has not been considered.

SECTION 6: STRUCTURAL STABILITY

6.1 EVALUATION OF EMBANKMENT STABILITY

a. Visual Observations - No signs of potential instability were observed during the visual inspections of Woodward Dam and Greenleaf Dam. The dams are generally well maintained. A seep was observed along the downstream toe of Woodward Dam during the visual inspection; however, this is believed to be related to the 8-inch blow-off pipe outlet that is shown on available plans for the structure.

b. Design and Construction Information - No design and construction information relating to stability is available for Woodward Dam or Greenleaf Dam.

c. Operating Records - Woodward and Greenleaf Dams are inspected daily by a watchman for the City of Middletown. The control valves in the gate house are operated periodically.

d. Post Construction Changes - Background information indicates that the dam may have been raised 2.5 feet in 1925. Plans were formulated in 1946-1947 for raising Woodward and Greenleaf Dams significantly to increase the storage area in Shawangunk Reservoir, but these plans were never implemented.

6.2 STABILITY ANALYSIS

The results of previous stability analyses, if any, were not available for Woodward Dam.

The dam appears to be a relatively homogeneous embankment composed largely of sandy silt (estimated to be ML Group Soils - Unified Classification System). The original plans for Woodward Dam indicate a masonry core wall, but test pits dug in past investigations reportedly revealed no evidence of this core wall. Woodward Dam is 29.7 feet high with a crest width of 9 feet. The upstream slope of the embankment is 1V:2.4H while the downstream slope is 1V:2.2H. The upstream slope is protected well with riprap with the exception of the top 4 to 5 feet below the crest. The dam is not subject to rapid drawdown (greater than 0.5 feet drop in the reservoir level per day) as determined by hydraulic calculations made during these investigations.

The slopes of Woodward Dam are slightly steep (particularly the upstream slope) and the crest width is narrow. However, a stability analysis is not considered necessary, based on the overall condition of the dam as observed during the visual inspection.

6.3 SEISMIC STABILITY

The dam is located in Seismic Zone 1 which presents no hazard from earthquakes, according to the Recommended Guidelines for Safety Inspection of Dams. This determination is contingent on the requirements that static stability conditions are satisfactory and conventional safety margins exist.

SECTION 7: ASSESSMENT/RECOMMENDATIONS

7.1 ASSESSMENT

a. Safety - Examination of available documents and visual inspections of Woodward Dam did not reveal any conditions which are considered to be hazardous.

Using the Corps of Engineers' screening criteria for review of spillway adequacy, it has been determined that the dam would be overtopped for all storms exceeding approximately 60 percent of the PMF. Therefore, the spillway is adjudged "inadequate."

b. Adequacy of Information - The information available and the observations and measurements made during the visual inspection are considered sufficient for this Phase I Inspection Report.

c. Need for Additional Information - No additional information is needed as a result of this Phase I Inspection Report. A stability analysis is not considered necessary at this time.

d. Urgency - The remedial measures listed below must be completed within one year from notification.

7.2 RECOMMENDED MEASURES

The regular inspections and maintenance procedures presently being conducted by the owner's representative appear to be adequate, although some form of documentation is needed. A thorough checklist should be compiled by the owner's representative and completed during each inspection. Maintenance items should be completed annually. Monitoring of the reservoir level should be expanded to include reservoir levels above normal pool.

The following remedial measures must be completed within one year.

Woodward Dam:

1. All low areas on the crest of the dam must be filled to the average crest elevation, compacted, and seeded.

2. Riprap must be placed on the upstream face of the dam above normal pool level.

3. The seep and wet areas at the toe of the dam must be monitored at regular intervals and during periods of high reservoir levels for turbidity and increase in flow, which may indicate potential for the piping of embankment material.

4. The eroded areas at the downstream end of the spillway discharge channel must be repaired and protected.

5. All trees and brush must be cut off at ground level on the downstream toe, upstream slope, and spillway discharge channel. The root systems of all trees with a trunk diameter greater than 3 inches must be removed from the downstream toe of the dam. All resultant areas of erosion and cavities must be filled, graded, compacted, and seeded.

6. The animal burrow at the toe of the dam must be filled, compacted, and seeded.

7. Spalled areas in the concrete of the gate house and concrete weir must be repaired.

8. A staff gage must be installed to monitor reservoir levels above normal pool.

Greenleaf Dam:

1. The seep at the toe of the dam must be monitored at regular intervals and during periods of high reservoir levels for turbidity and increase in flow, which may indicate potential for the piping of embankment material.

2. Riprap must be placed on the upstream face of the dam above normal pool level.

3. All trees and brush must be cut off at ground level on the downstream toe of the dam. The root systems of all trees with a trunk diameter greater than 3 inches are to be removed. All resultant areas of erosion and cavities must be filled, graded, compacted, and seeded.

4. The animal burrow and depression on the downstream side of the dam must be filled, graded, compacted, and seeded.

APPENDIX A

PHOTOGRAPHS

CONTENTS

Photo 1. Upstream Face of Dam from Left Abutment
9 March 1981

Photo 2. Downstream Face of Dam from Right Abutment
9 March 1981

Photo 3. Gatehouse from Reservoir Side of Dam
9 March 1981

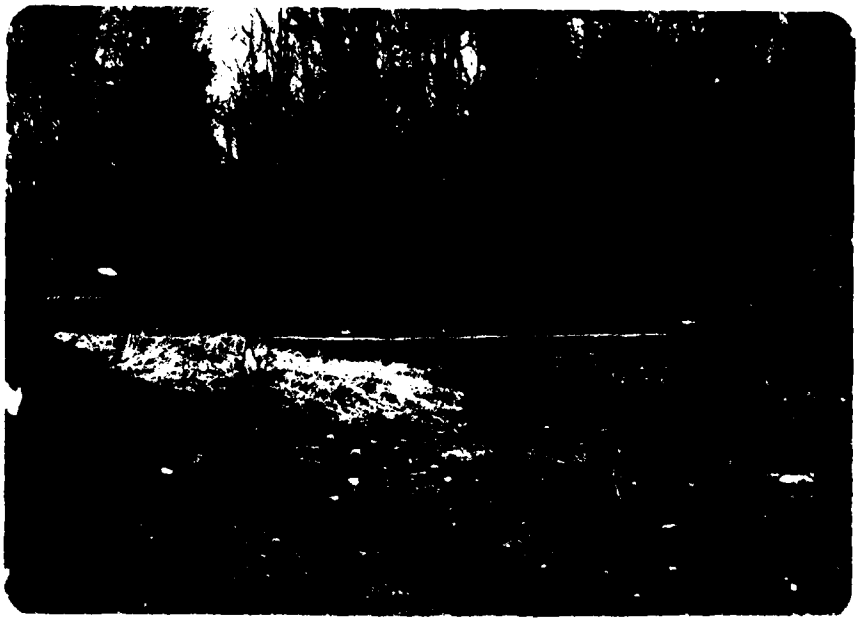


Photo 4. Spillway from Upstream Side
9 March 1981

Photo 5. Spillway Discharge Channel with Collapsed Training Wall under Bridge (from Downstream Side of Bridge) 9 March 1981

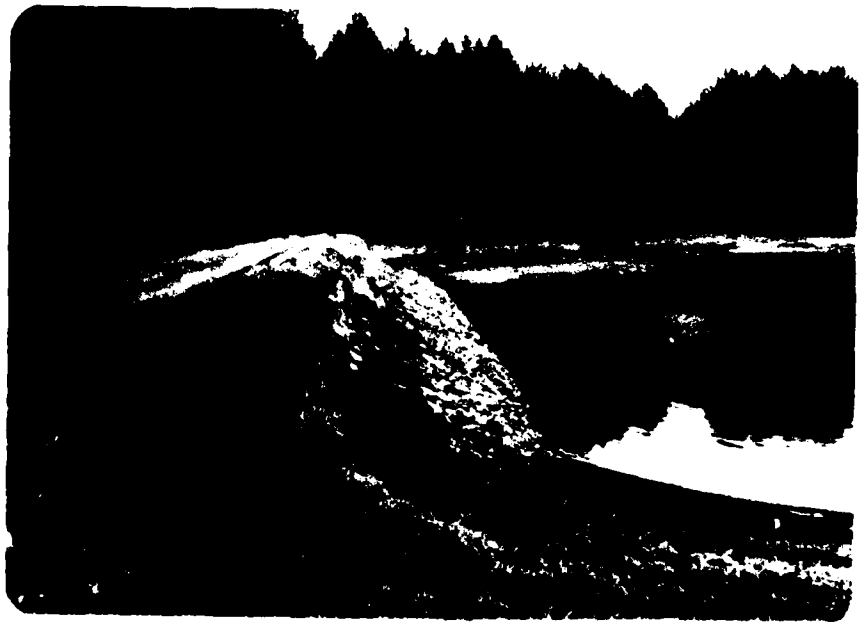


Photo 6. Upstream Face of Greenleaf Dam from Left Abutment 9 March 1981

APPENDIX B

VISUAL INSPECTION CHECKLIST

VISUAL INSPECTION CHECKLIST

1) Basic Data

a. General

Name of Dam Woodward Dam

Fed. I.D. # NY 507 DEC Dam No. 179A-562

River Basin Hudson

Location: Town Mount Hope County Orange

Stream Name Little Shawangunk Kill

Tributary of

Latitude (N) 41°27.0' Longitude (W) 74°29.7'

Type of Dam Earth embankment

Hazard Category High

Date(s) of Inspection 10 January 1981

Weather Conditions Sunny 20°

Reservoir Level at Time of Inspection 753.4 ft. M.S.L.

b. Inspection Personnel Wayne D. Lasch, Gary W. Todd, Rory L. Galloway

c. Persons Contacted (Including Address & Phone No.)

Bill Johnson, City Hall

16 James Street

Middletown, NY 10940

914/343-3169

d. History:

Date Constructed 1901 Date(s) Reconstructed 1925

Designer W.R. Hill - Consulting Engineer
D.R. Lee - Resident Engineer

Constructed By Unknown

Owner City of Middletown, NY

2) Embankment

a. Characteristics

(1) Embankment Material Earth (sandy silt)

(2) Cutoff Type None

(3) Impervious Core Reported to be masonry core. However, previous test pits by owner failed to locate any masonry core.

(4) Internal Drainage System None observed

(5) Miscellaneous Snow covered at time of inspection, 2-6 in. on dam.

b. Crest

(1) Vertical Alignment Minor low areas located between Sta. 2+00 and 3+00.

(2) Horizontal Alignment Good

(3) Surface Cracks None observed at time of inspection.

(4) Miscellaneous Good grass cover on crest.

c. Upstream Slope

(1) Slope (Estimate) (V:H) 1:2.4

(2) Undesirable Growth or Debris, Animal Burrows Small amount of brush growing on slope.

(3) Sloughing, Subsidence, or Depressions Minor erosion (riprap displacement) at normal pool level.

(4) Slope Protection Quartzite riprap protection extending from normal pool level to water surface at time of inspection.

(5) Surface Cracks or Movement at Toe Unobservable at time of inspection.

d. Downstream Slope

(1) Slope (Estimate - V:H) 1:2.2

(2) Undesirable Growth or Debris, Animal Burrows Trees (2 to 24 in. diameter) and brush along toe of dam.

(3) Sloughing, Subsidence or Depressions None observed at time of inspection.

(4) Surface Cracks or Movement at Toe None observed at time of inspection.

(5) Seepage Approx. 0.5 g.p.m. at toe of dam (Sta. 2+30), wet area (approx. 10 sq. ft.) at toe of dam at Sta. 2+70.

(6) External Drainage System (Ditches, Trenches, Blanket) None observed

(7) Condition Around Outlet Structure None observed at time of inspection.

(8) Seepage Beyond Toe None observed

e. Abutments - Embankment Contact Appeared good at time of inspection.

(1) Erosion at Contact None observed at time of inspection.

(2) Seepage Along Contact None observed at time of inspection.

3) Drainage System

a. Description of System None

b. Condition of System None

c. Discharge from Drainage System None

4) Instrumentation (Monumentation/Surveys, Observation Wells, Weirs, Piezometers, Etc.) None observed

5) Reservoir

a. Slopes Mild to moderate slopes, heavily wooded.

b. Sedimentation Minor problem, sediments currently being removed to increase capacity.

c. Unusual Conditions Which Affect Dam Highland Lake Dam upstream, 400 ft. long, 30 ft. high, 15 ft. crest width.

6) Area Downstream of Dam

a. Downstream Hazard (No. of Homes, Highways, etc.) Mapes road and 1 home 3200 ft. downstream, economic damage only.

b. Seepage, Unusual Growth None observed at time of inspection.

c. Evidence of Movement Beyond Toe of Dam None observed at time of inspection.

d. Condition of Downstream Channel Rocks, large trees and local debris in channel.

7) Spillway(s) (Including Discharge Conveyance Channel)

Spillway is located on the right upstream side of the crest.

a. General Low concrete weir with masonry training walls. Wooden bridge (5 ft. x 20 ft.) crosses training walls along crest of dam.

b. Condition of Service Spillway Concrete weir has relatively major spalling especially on the downstream face.

c. Condition of Auxiliary Spillway None

d. Condition of Discharge Conveyance Channel Masonry training walls have many voids. Right training wall under bridge is collapsing. Discharge channel has rocks, trees and local debris. Severe erosion of channel banks at downstream end.

8) Reservoir Drain/Outlet

Type: Pipe _____ Conduit X Other _____

Material: Concrete _____ Metal cast iron Other _____

Size: 20 in. Length 19,500 ft.

Invert Elevations: Entrance 738.0 ft.

Exit 712.0 ft. (Estimated)

Physical Condition (Describe): Unobservable X

Material: _____

Joints: _____ Alignment _____

Structural Integrity: _____

_____

_____

Hydraulic Capability: _____

_____

Means of Control: Gate _____ Valve 20 in. Uncontrolled _____

Operation: Operable X Inoperable _____ Other _____

Present Condition (Describe): Owner reported valves are operated regularly.

_____

_____

_____

9) Structural - Not Applicable

a. Concrete Surfaces _____

_____

_____

_____

b. Structural Cracking _____

_____

_____

c. Movement - Horizontal & Vertical Alignment (Settlement) _____

_____

_____

d. Junctions with Abutments or Embankments _____

_____

_____

e. Drains - Foundation, Joint, Face _____

f. Water Passages, Conduits, Sluices _____

g. Seepage or Leakage _____

h. Joints - Construction, etc. _____

i. Foundation _____

j. Abutments _____

k. Control Gates _____

l. Approach & Outlet Channels _____

m. Energy Dissipators (Plunge Pool, etc.) _____

n. Intake Structures _____

o. Stability _____

p. Miscellaneous _____

10) Appurtenant Structures (Power House, Lock, Gatehouse, Other)

a. Description and Condition Gatehouse is a 14 ft. x 28 ft. brick structure located on the upstream face of the dam. Spalled areas on the gatehouse foundation have been recently patched but patches are deteriorating.

VISUAL INSPECTION CHECKLIST

1) Basic Data

a. General

Name of Dam Greenleaf Dam

Fed. I.D. # NY 508 DEC Dam No. _____

River Basin Hudson

Location: Town Mount Hope County Orange

Stream Name Little Shawangunk Kill

Tributary of _____

Latitude (N) 41°26.85' Longitude (W) 74°30.24'

Type of Dam Earth embankment

Hazard Category High

Date(s) of Inspection 10 January 1981

Weather Conditions Sunny 20°

Reservoir Level at Time of Inspection 753.4 ft. M.S.L.

b. Inspection Personnel Wayne D. Lasch, Gary W. Todd,
Rory L. Galloway

c. Persons Contacted (Including Address & Phone No.) _____
Bill Johnson, City Hall
16 James Street
Middletown, NY 10940
914/343-3169

d. History:

Date Constructed 1901 Date(s) Reconstructed 1925

Designer Unknown

Constructed By Unknown

Owner City of Middletown, NY

2) Embankment

a. Characteristics

(1) Embankment Material Earth embankment

(2) Cutoff Type None

(3) Impervious Core None

(4) Internal Drainage System None observed

(5) Miscellaneous Snow covered at time of inspection, 2-6 in. on dam.

b. Crest

(1) Vertical Alignment Good

(2) Horizontal Alignment Good

(3) Surface Cracks None observed at time of inspection.

(4) Miscellaneous Snow covered at time of inspection.

c. Upstream Slope

(1) Slope (Estimate) (V:H) 1:2

(2) Undesirable Growth or Debris, Animal Burrows None observed at time of inspection.

(3) Sloughing, Subsidence, or Depressions Minor erosion (riprap displacement) at normal pool level.

(4) Slope Protection Quartzite riprap protection extending from normal pool level to water surface at time of inspection.

(5) Surface Cracks or Movement at Toe Unobservable at time of inspection.

d. Downstream Slope

(1) Slope (Estimate - V:H) 1:2

(2) Undesirable Growth or Debris, Animal Burrows Trees (2-24 in. diameter) and brush along toe of dam.

(3) Sloughing, Subsidence or Depressions None observed at time of inspection.

(4) Surface Cracks or Movement at Toe None observed at time of inspection.

(5) Seepage None observed at time of inspection.

(6) External Drainage System (Ditches, Trenches, Blanket) None

(7) Condition Around Outlet Structure None

(8) Seepage Beyond Toe None

e. Abutments - Embankment Contact Appeared good at time of inspection.

(1) Erosion at Contact None observed at time of inspection.

(2) Seepage Along Contact None observed at time of inspection.

3) Drainage System

a. Description of System None

b. Condition of System None

c. Discharge from Drainage System None

4) Instrumentation (Monumentation/Surveys, Observation Wells, Weirs, Piezometers, Etc.) None

5) Reservoir

a. Slopes Moderate slopes, heavily wooded.

b. Sedimentation Minor problem, sediments currently being removed to increase capacity.

c. Unusual Conditions Which Affect Dam Highland Lake Dam upstream, 400 ft. long, 30 ft. high, 15 ft. crest width.

6) Area Downstream of Dam

a. Downstream Hazard (No. of Homes, Highways, etc.) 1 small pond 200 ft. directly downstream, Mapes road and 1 home downstream.

b. Seepage, Unusual Growth None observed at time of inspection.

c. Evidence of Movement Beyond Toe of Dam None observed at time of inspection.

d. Condition of Downstream Channel Mild slopes with trees and debris in channel.

7) Spillway(s) (Including Discharge Conveyance Channel)

None

a. General _____

b. Condition of Service Spillway _____

c. Condition of Auxiliary Spillway _____

d. Condition of Discharge Conveyance Channel _____

8) Reservoir Drain/Outlet - None

Type: Pipe _____ Conduit _____ Other _____

Material: Concrete _____ Metal _____ Other _____

Size: _____ Length _____

_____ _____

Invert Elevations: Entrance _____

Exit _____

Physical Condition (Describe): Unobservable _____

Material: _____

Joints: _____ Alignment _____

Structural Integrity: _____

_____

_____

Hydraulic Capability: _____

_____ _____

Means of Control: Gate _____ Valve _____ Uncontrolled _____

Operation: Operable _____ Inoperable _____ Other _____

Present Condition (Describe): _____

_____

_____

_____

_____

9) Structural - Not Applicable

a. Concrete Surfaces _____

_____

_____

_____

b. Structural Cracking _____

_____

_____

c. Movement - Horizontal & Vertical Alignment (Settlement) _____

_____

_____

d. Junctions with Abutments or Embankments _____

_____

_____

e. Drains - Foundation, Joint, Face _____

f. Water Passages, Conduits, Sluices _____

g. Seepage or Leakage _____

h. Joints - Construction, etc. _____

i. Foundation _____

j. Abutments _____

k. Control Gates _____

l. Approach & Outlet Channels _____

_____

_____

_____

m. Energy Dissipators (Plunge Pool, etc.) _____

_____

_____

n. Intake Structures _____

_____

_____

_____

o. Stability _____

_____

p. Miscellaneous _____

_____

_____

10) Appurtenant Structures (Power House, Lock, Gatehouse, Other)

a. Description and Condition None

_____

_____

_____

_____

APPENDIX C

HYDROLOGIC/HYDRAULIC DATA AND COMPUTATIONS

MICHAEL BAKER, JR., INC.
THE BAKER ENGINEERS

Box 280
Beaver, Pa. 15009

Subject Woodward Dam S.O. No. _____
Appendix C - Hydrologic/Hydraulic Sheet No. _____ of _____
Engineering Data and Computations Drawing No. _____
Computed by _____ Checked by _____ Date _____

SUBJECT	PAGE

CHECK LIST FOR DAMS
HYDROLOGIC AND HYDRAULIC
ENGINEERING DATA

AREA-CAPACITY DATA:

		Elevation (ft.)	Surface Area (acres)	Storage Capacity (acre-ft.)
1)	Top of Dam	769.7	125.4	1633
2)	Design High Water (Max. Design Pool)	-	-	-
3)	Auxiliary Spillway Crest	-	-	-
4)	Pool Level with Flashboards	-	-	-
5)	Service Spillway Crest	767.0	100.7	1332

DISCHARGES

		Volume (cfs)
1)	Average Daily	Unknown
2)	Spillway @ Maximum High Water - Top of Dam - (El. 769.7 ft. M.S.L.)	532
3)	Spillway @ Design High Water	Unknown
4)	Spillway @ Auxiliary Spillway Crest Elevation	-
5)	Low Level Outlet (20 in. C.I.P.)	6
6)	Total (of all facilities) @ Maximum High Water	538
7)	Maximum Known Flood	Unknown
8)	At Time of Inspection	0

CREST: ELEVATION: 769.7 ft.

Type: Earthfill dam

Width: 9 ft. Length: 463 ft.

Spillover Low, broad-crested weir

Location 50 ft. from right abutment and 18 ft. upstream from the crest of the dam.

SPILLWAY:

SERVICE		AUXILIARY
767.0 ft.	Elevation	None
Broad-crested weir	Type	-
18.7 ft.	Width	-
	Type of Control	
X	Uncontrolled	-
	Controlled:	
-	Type (Flashboards; gate)	-
-	Number	-
-	Size/Length	-
	Invert Material	-
	Anticipated Length of Operating Service	-
-	Chute Length	-
0.8 ft.	Height Between Spillway Crest & Approach Channel Invert (Weir Flow)	-

HYDROMETEROLOGICAL GAGES:

Type: None

Location:

Records:

Date:

Max. Reading:

FLOOD WATER CONTROL SYSTEM:

Warning System: None

Method of Controlled Releases (mechanisms):

A 20 in. gravity fed water supply line approximately 19,500 ft. long to Monhagen Lake.

DRAINAGE AREA: 1.50 sq. mi.

DRAINAGE BASIN RUNOFF CHARACTERISTICS:

Land Use - Type: Wooded with light residential development.

Terrain - Relief: Moderate slopes.

Surface - Soil: Well drained.

Runoff Potential (existing or planned extensive alterations to existing surface or subsurface conditions)

There were no known plans for altering the existing runoff paterns at the time of inspection.

Potential Sedimentation problem areas (natural or man-made; present or future)

None observed at the time of inspection.

Potential Backwater problem areas for levels at maximum storage capacity including surcharge storage:

None observed at the time of inspection.

Dikes - Floodwalls (overflow & non-overflow) - Low reaches along the Reservoir perimeter:

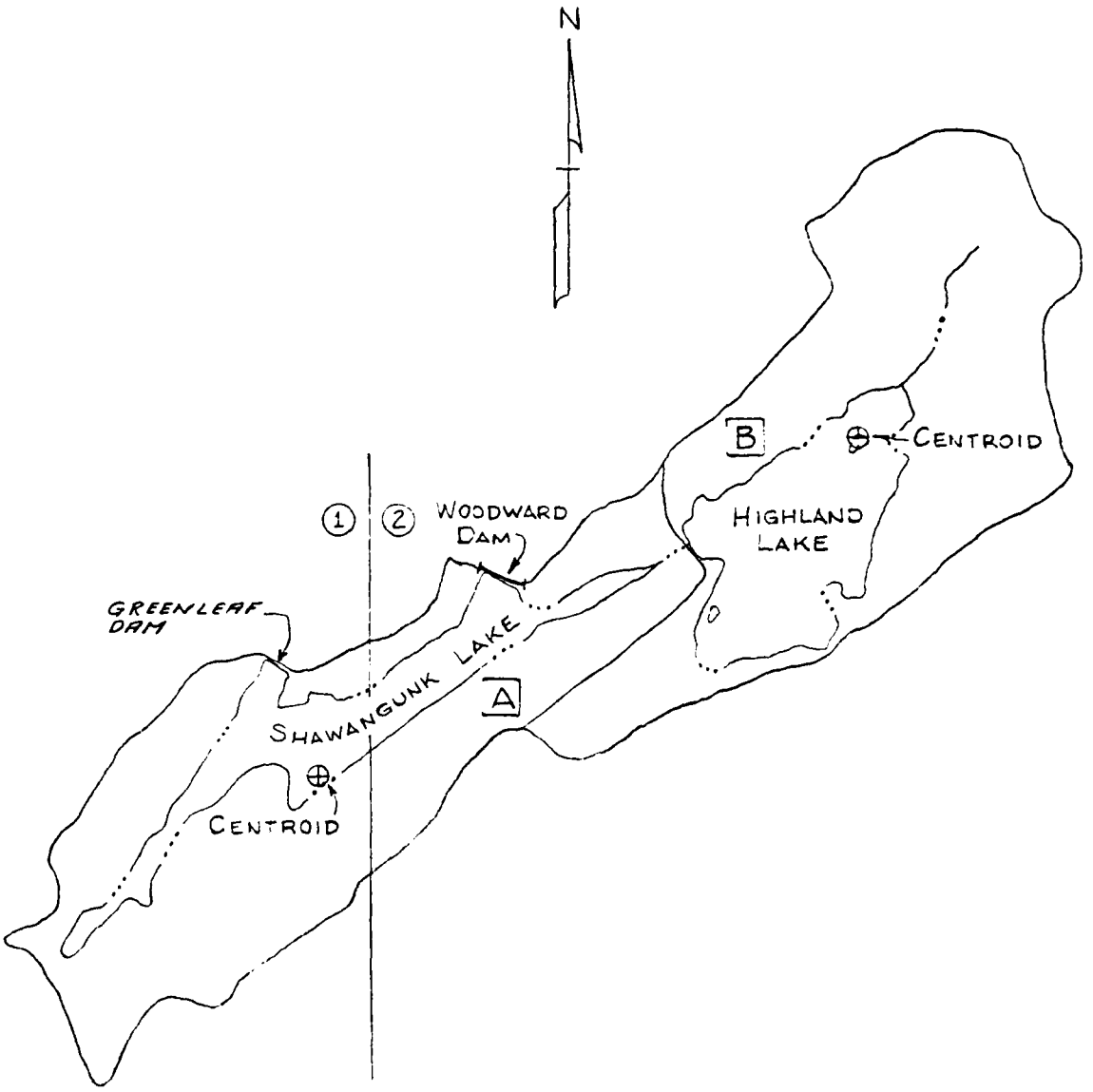
Location: None

Elevation:

Reservoir:

Length @ Maximum Pool 8,500 ft. (El. 769.7 ft. M.S.L.)

Length of Shoreline (@ Spillway Crest) 20,800 ft. (3.94 mi.)
(El. 767.0 ft. M.S.L.)



QUADS: ① OTISVILLE, N.Y.
② MIDDLETOWN, N.Y.

DRAINAGE AREA [A] = 0.72 SQ. MI.

DRAINAGE AREA [B] = 0.78 SQ. MI.

DRAINAGE AREA ABOVE
WOODWARD DAM

SCALE: 1 IN. = 2000 FT.

MICHAEL BAKER, JR., INC.
THE BAKER ENGINEERS
Box 280
Beaver, Pa. 15009

Subject NEW YORK DAMS — S.O. No.
WOODWARD DAM — Sheet No. 6 of 38
Drawing No.
Computed by WLS #112 — Checked by — Date 1/22/81

HYDROLOGIC AND HYDRAULIC DATA

TOTAL DRAINAGE AREA ABOVE WOODWARD DAM = 10.45 SQ. IN.
(MEASURED ON OTISVILLE AND MIDDLETOWN, N.Y. QUADS)
= 1.50 SQ. MI.

DRAINAGE AREA BETWEEN WOODWARD DAM AND HIGHLAND LAKE DAM = 0.72 SQ. MI

$T_p = C_T (L \times L_{ca})^{.3}$

$C_T = 2.0 \quad C_p = .63$

$T_p = 2.0 [(1.59)(.61)]^{.3}$

$T_p = 1.98$

$L = 8400$ FT. $= 1.59$ MI

$L_{ca} = 3200$ FT $= 0.61$ MI

SURFACE AREA – ELEVATION (FROM QUAD)

ELEV. (FT)	AREA (AC.)
767	100.7
760	218.8

* From plaque @ Valve house – capacity 434,024,999 gal. (1332.06 Ac-Ft.)

DRAINAGE AREA ABOVE HIGHLAND LAKE DAM = 0.78 SQ. MI

$T_p = C_T (L \times L_{ca})^{.3}$

$C_p = 0.63 \quad C_T = 2.0$

$T_p = 2.0 [(1.21)(0.45)]^{.3}$

$= 1.67$

$L = 6400$ FT $= 1.21$ MI

$L_{ca} = 2400$ FT $= 0.45$ MI

SURFACE AREA – ELEVATION (FROM QUAD)

ELEV. (FT.)	AREA (AC.)
792	117.5
800	152.4

NOTE. NORMAL POOL OF HIGHLAND LAKE ASSUMED TO BE AT EL. 792 (AS SHOWN ON PLANS)

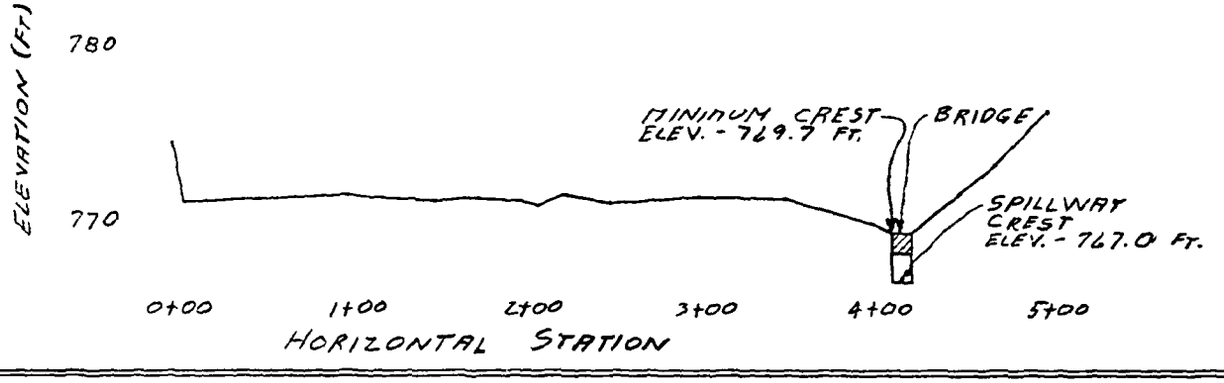
MICHAEL BAKER, JR., INC.
THE BAKER ENGINEERS

Box 280
Beaver, Pa. 15009

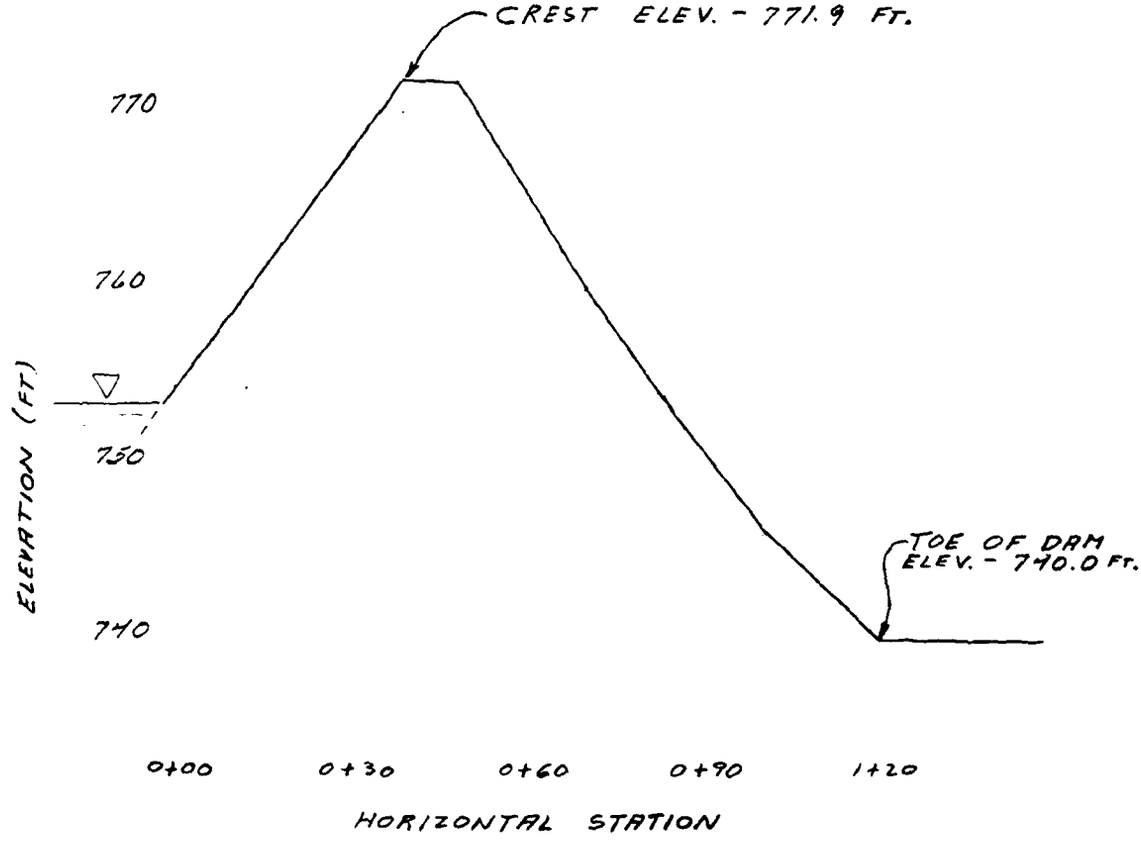
Subject WOODWARD DAM S.O. No.
TOP OF DAM PROFILE AND Sheet No. 7 of 38
TYPICAL CROSS SECTION Drawing No.
Computed by GWT Checked by WLS Date 1-19-81

TOP OF DAM PROFILE (LOOKING DOWNSTREAM)

LENGTH OF DAM = 463 FT.



TYPICAL CROSS SECTION AT STATION 2+30



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THE BAKER ENGINEERS

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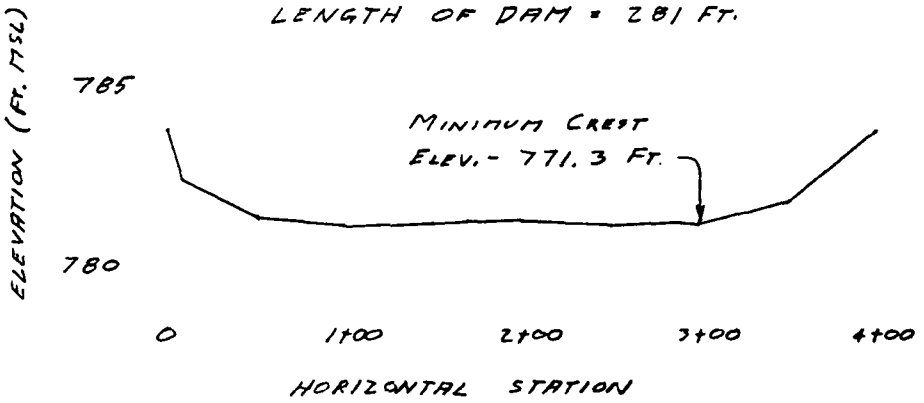
Beaver, Pa. 15009

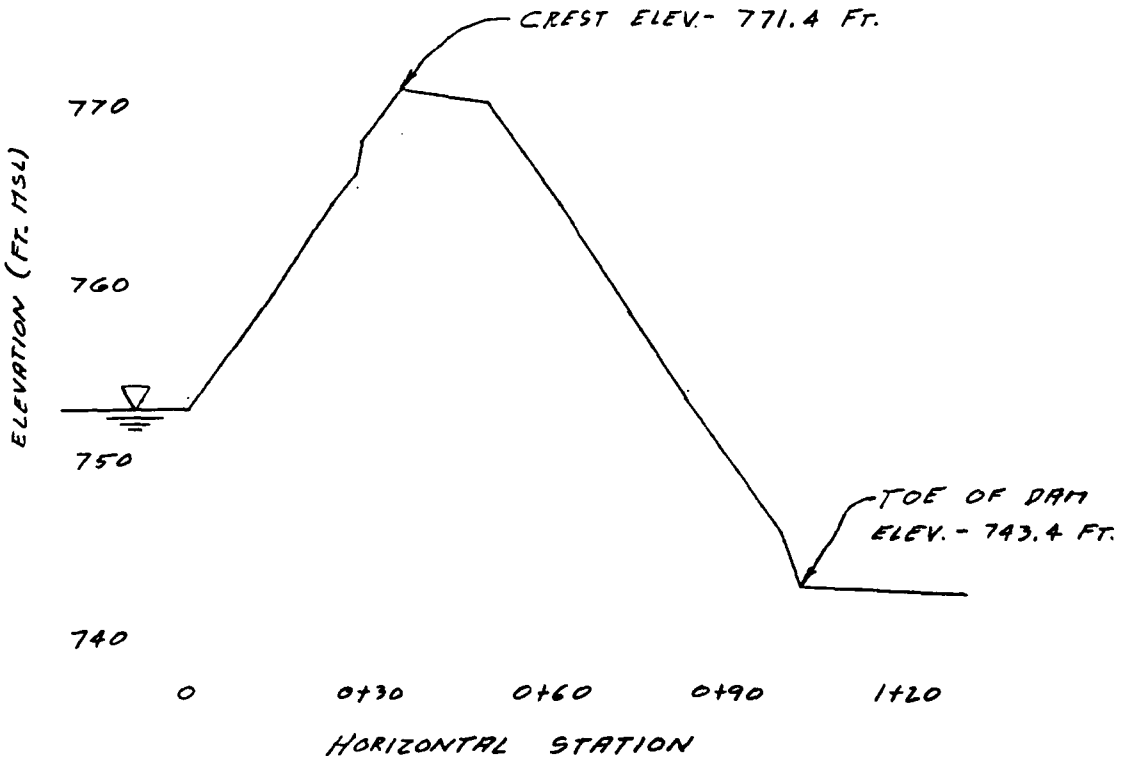
Subject GREENLEAF DAM S.O. No. _____
TOP OF DAM PROFILE AND Sheet No. 8 of 38
TYPICAL CROSS SECTION Drawing No. _____
Computed by GWT Checked by _____ Date 2-12-81

TOP OF DAM PROFILE (LOOKING DOWNSTREAM)

LENGTH OF DAM = 281 FT.



TYPICAL CROSS SECTION AT STATION 1+68

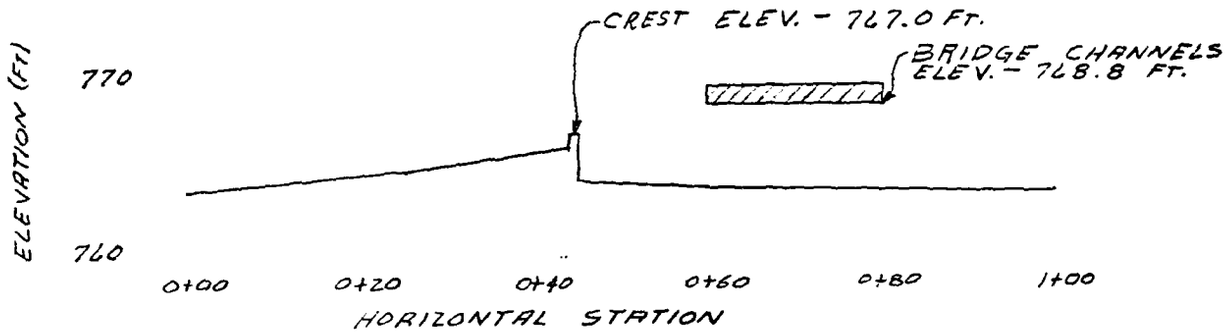


MICHAEL BAKER, JR., INC.
THE BAKER ENGINEERS

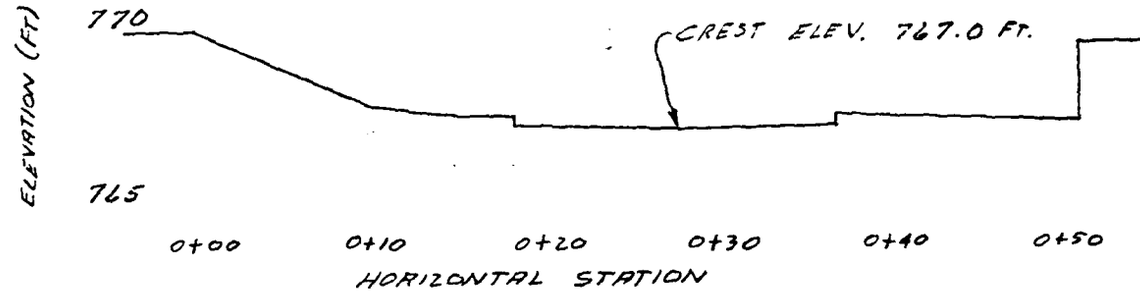
Box 280
Beaver, Pa. 15009

Subject WOODWARD DAM S.O. No.
SPILLWAY PROFILE AND Sheet No. 9 of 38
CROSS SECTION Drawing No.
Computed by GWT Checked by LWLS Date 1-19-81

SPILLWAY CROSS SECTION



SPILLWAY PROFILE



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THE BAKER ENGINEERS

Box 280
Beaver, Pa. 15009

Subject WOODWARD DAM S.O. No.
SPILLWAY DISCHARGE RATING Sheet No. 10 of 38
Drawing No.
Computed by GWT Checked by WLS Date 1-20-81

SPILLWAY RATING

DEVELOPE RATING CURVE BASED UPON CRITICAL FLOW OVER SPILLWAY:

$V = \sqrt{gD}$ CHOW, OPEN CHANNEL HYDRAULICS, P. 43

$g = 32.2$ FT/SEC²

D = MEAN HYDRAULIC DEPTH = $\frac{\text{FLOW AREA}}{\text{TOP WIDTH}} = \frac{A}{T}$

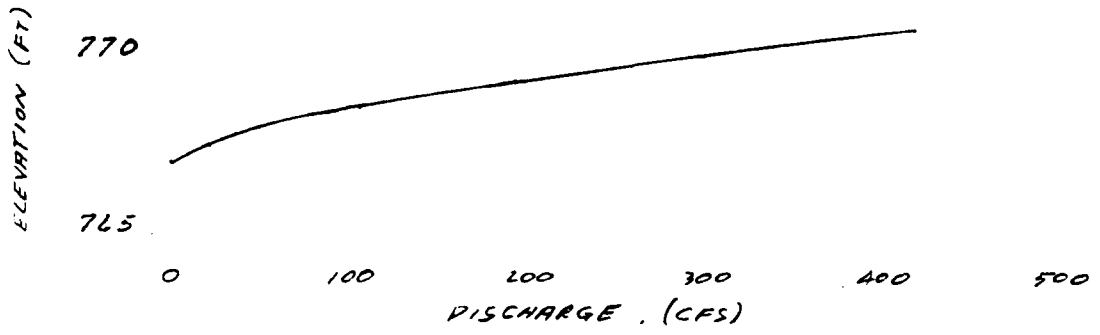
V = MEAN FLOW VELOCITY

$Q = AV$

SPILLWAY

ELEVATION, (FT)	FLOW DEPTH, (FT)	AREA, (FT²)	TOP WIDTH (FT)	A/T	V, FT/SEC	Q, (CFS)	V²/2g	RESERVOIR ELEV.
767.0	0'	0'	18.7'	0'	0'	0'	0'	777.0
767.5	.5'	9.35'	18.7'	0.50'	4.01'	37.52	.25'	777.7
768.0	1.0'	18.70'	18.7'	1.00'	5.67'	106.03'	.50'	778.5
768.5	1.5'	28.05'	18.7'	1.50'	6.95'	194.95'	.75'	779.2
769.0	2.0'	37.40'	18.7	2.00'	8.02'	300.13	1.00'	780.0
769.5	2.5'	46.75'	18.7	2.50'	8.97'	419.45'	1.25'	780.7

SPILLWAY DISCHARGE CURVE



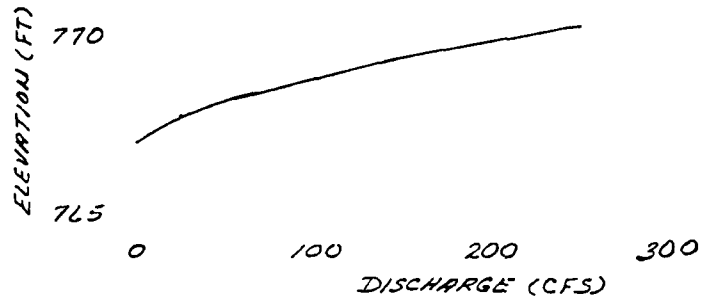
MICHAEL BAKER, JR., INC.
THE BAKER ENGINEERS

Box 280
Beaver, Pa. 15009

Subject Woodward Dam S.O. No.
Spillway Discharge Rating Sheet No. 11 of 39
(Continued) Drawing No.
Computed by GWT/ALE Checked by Date 1/20/81

Right Training Wall

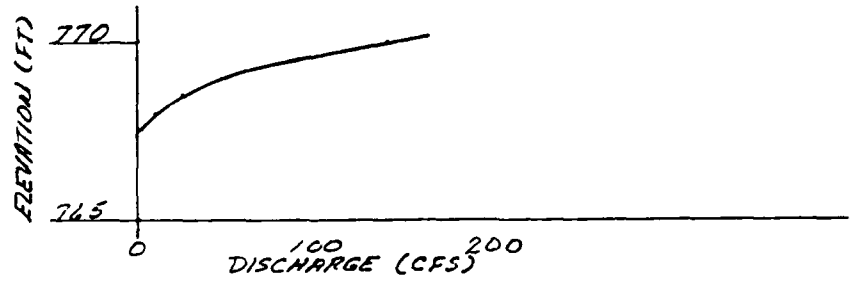
ELEVATION (FT)	FLOW DEPTH (FT)	AREA (FT^2)	TOPWIDTH (FT)	A/T	V (FT/SEC)	Q (CFS)	$V^2/2g$	RESERVOIR ELEVATION
767.2	0	0	0	0	0	0	0	777.2
767.5	.3	2.10	14	.15	2.20	4.62	.07	777.57
768.0	.8	9.10	14	.65	4.57	41.63	.32	778.32
768.5	1.3	16.10	14	1.15	6.08	97.97	.57	779.07
769.0	1.8	23.10	14	1.65	7.29	168.38	.82	779.82
769.5	2.3	30.10	14	2.15	8.32	250.44	1.07	780.57



Left Training Wall

ELEVATION (FT)	FLOW DEPTH (FT)	AREA (FT^2)	TOPWIDTH (FT)	A/T	V (FT/SEC)	Q (CFS)	$V^2/2g$	RESERVOIR ELEVATION
767.4	0	0	3.5	0	0	0	0	777.4
767.5	.1	.72	5.0	0.08	1.60	0.67	0.04	777.54
768.0	.6	4.57	9.5	0.48	3.93	17.96	0.24	778.24
768.5	1.1	9.95	12.0	0.83	5.17	51.44	0.42	778.92
769.0	1.6	16.58	14.5	1.14	6.06	100.47	0.57	779.57
769.5	2.1	24.33	16.5	1.47	6.88	167.39	0.74	780.24

Spillway Rating Curve



MICHAEL BAKER, JR., INC.
THE BAKER ENGINEERS

Box 280
Beaver, Pa. 15009

Subject: EDGEWARD DAM — S.O. No.
SPILLWAY DISCHARGE RATING SUMMARY — Sheet No. 12 of 38 — Drawing No.
Computed by GWT/MLB — Checked by — Date 01/29/80

SPILLWAY DISCHARGE SUMMARY

ELEVATION (FT)	SPILLWAY (CFS)	RT. TRAINING WALL (CFS)	LT. TRAINING WALL (CFS)	TOTAL (CFS)
767.0	0	0	0	0
767.5	22.0	4.0	1.0	29.0
768.0	50.0	36.0	10.0	96.0
768.5	106.0	55.0	24.0	185.0
769.0	160.0	97.0	51.0	308.0
769.5	230.0	140.0	95.0	465.0
770.0	300.0	190.0	142.0	632.0

MICHAEL BAKER, JR., INC.
THE BAKER ENGINEERS

Box 280
Beaver, Pa. 15009

Subject Woodward Dam S.O. No.

Sheet No. 13 of 38

20" Dia Pipe Outflow Rating Drawing No.

Computed by JE Checked by Date 2/10/81

Pipe Flow

$$Q = \frac{A(2gh)^{1/2}}{[1+K_e+K_b+K_c(L)]^{1/2}}$$

$$= \frac{2.16(2\times32.2\times h)^{1/2}}{[1+0.78+0.39+0.0185(19,500)]^{1/2}}$$

$$= \frac{17.334\,h^{1/2}}{19.0505}$$

$$= 0.9099\,h^{1/2}$$

Pipe is 20" Dia Cast Iron Pipe

$A = \pi r^2 = \pi(0.83)^2 = 2.16$ ft.^{2}

$g = 32.2$ ft./sec^2

h = head measured from the top of Pipe @ outlet (est. @ 712.0 ft.)*

$L = 19,500$ ft.*

$K_e = 0.78$ Pg 5.5-6 SCS NEH-5

$K_b = 0.39$ (est)* Pg 5.5-10 "

$K_c = 0.0185$ Pg 5.5-A "

"n" = 0.014 (Uncoated Cast Iron Pipe)

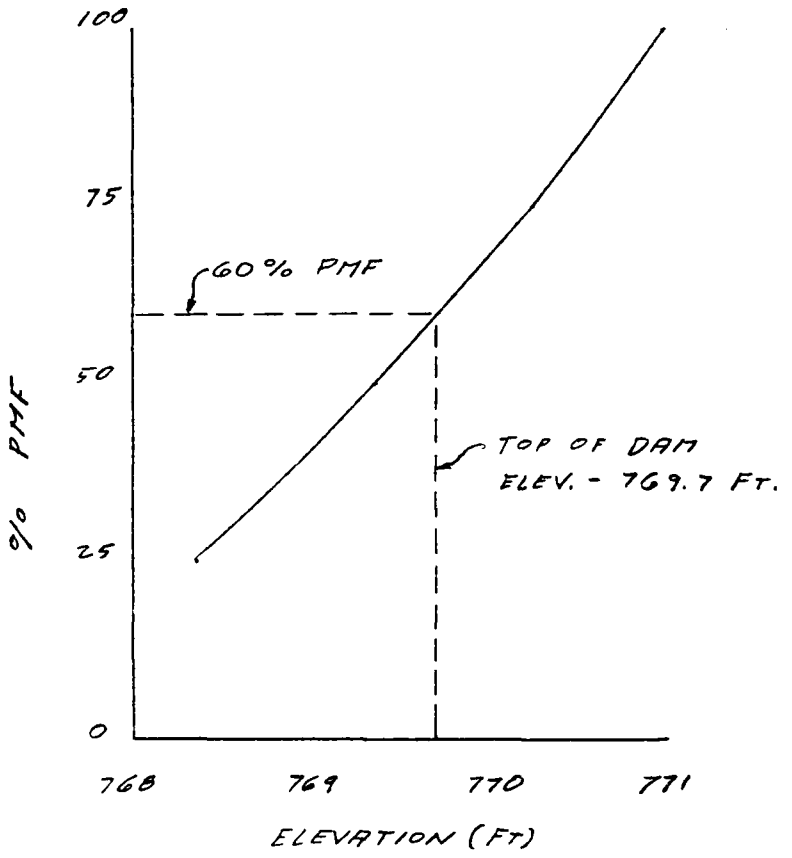
	Elev. (ft.)	h (ft.)	Q (cfs)
Invert of Drain	738	26	0
	739	27	4.73
	740	28	4.81
	742	30	4.98
	744	32	5.15
	746	34	5.31
	748	36	5.46
	750	38	5.61
	754	42	5.90
	758	46	6.17
	762	50	6.43
	766	54	6.69
Spillway Crest	767	55	6.75

* Note: The route traveled by the drain pipe is unknown. The outlet was not located in the field. The length and outlet elevation of the pipe are estimated by knowing the approximate area of the outlet (Manhagen Lake - Normal pool elev. 712 ft.) The number and degree of bends in this pipe are unknown. One 90° bend was assumed for use in this rating curve.

MICHAEL BAKER, JR., INC.
THE BAKER ENGINEERS

Box 280
Beaver, Pa. 15009

Subject WOODWARD DAM S.O. No.
SPILLWAY CAPACITY ANALYSIS Sheet No. 14 of 35
Drawing No.
Computed by GWT Checked by Date 2-10-81



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**********************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION        JULY 1978
 LAST MODIFICATION   26 FEB 77
  MBJ UPDATE          04 JUN 79        FLOOD   ROUTING
**********************************
      A1        NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS
      A2        HYDROLOGIC AND HYDRAULIC ANALYSIS OF WOODWARD DAM
      A3        UNIT HYDROGRAPH BY SNYDERS METHOD
      B     600       0      20       0       0       0       0       0      -4       0
      B1      5
      J       1       4       1
      J1    1.0    0.75     0.5    0.25
      K       0       1                                               1
      K1        RUNOFF COMPUTATION FOR SUBAREA A
      M       1       1    0.78
      P            21.2     111     123     133     142
      T                                                             1.0     0.1
      W    1.93     .63
      X    -1.5   -0.05       2
      K       1       2                                               1
      K1        ROUTING SUBAREA A THROUGH HIGHLAND LAKE DAM
      Y                                       1       1
      Y1      1                                                  -792.0      -1
      Y4  792.0   792.5   793.0   794.0   795.0   796.0   797.0   798.0   799.0   799.5
      Y5      0       5      30      72     129     206     285     383     484     500
      $A      0   117.5   152.4
      $E    732     792     800
      $$  797.0
      $D  797.0    3.08     1.5     470
      $L    330     377     463     597     730     869    1009    1148
      $V  797.0   797.5   798.0   799.0   800.0   802.0   804.0   806.0
      K       1       3                                               1
      K1        CHANNEL ROUTING SUBAREA A TO WOODWARD DAM
      Y                                       1       1
      Y1      1                                                      -1
      Y6    .03     .04     .08   767.0   810.0   460.0    .052
      Y7      0     810     270     800     330     780     520     777     780     780
      Y7    830     734    1040     800    1120     810
      K       0       4                                               1
      K1        RUNOFF COMPUTATION FOR SUBAREA B
      M       1       1    0.72
      P            21.2     111     123     133     142
      T                                                             1.0     0.1
      W    1.57     .33
      X    -1.5   -0.05       2
      K       2       5                                               1
      K1        COMBINED HYDROGRAPHS FOR SUBAREAS A AND B
      K       1       6                                               1
      K1        ROUTING FOR WOODWARD DAM
      Y                                       1       1
      Y1                                                         -767.0      -1
      Y4  767.0   767.5   768.0   768.5   769.0   769.5   770.0
      Y5      0      27      96     185     308     465     632
      $A   8.05  131.25   218.8
      $E    755     767     780
```

51		$$	767.3									
52		$D	769.7	3.03	1.5	144						
53		$L	3	20	69	78	239	407	590	781	828	910
54		$V	769.7	770.0	771.0	771.3	771.4	771.6	771.8	772.0	773.0	775.0
55		K	33									

SHEET 16 OF 33

****
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION JULY 1978
LAST MODIFICATION 26 FEB 79
ADD UPDATE 04 JUN 79
****

RUN DATE 02/10/81
TIME 15.11

NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS
HYDROLOGIC AND HYDRAULIC ANALYSIS OF WOODWARD DAM
UNIT HYDROGRAPH BY SNYDERS METHOD

JOB SPECIFICATION

NJ	NSR	NMIN	IDAY	IHR	IMIN	METRC	IPLT	IPRT	NSTAN
600	3	20	0	6	0	0	0	-4	0

JOPER	NWT	LROPT	TRACE
5	0	0	0

MULTI-PLAN ANALYSES TO BE PERFORMED
NPLAN= 1 NRTIO= 4 LRTIO= 1
RTIOS= 1.00 0.75 0.50 0.25

********** ********** ********** ********** **********

SUB-AREA RUNOFF COMPUTATION

RUNOFF COMPUTATION FOR SUBAREA A

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
1	0	0	0	0	0	1	0	0

HYDROGRAPH DATA

IHYDG	IUHG	TAREA	SNAP	TRSDA	TRSPC	RATIO	ISAME	LOCAL
1	1	0.78	0.0	0.78	0.0	0.0	0	0	0

PRECIP DATA

SPFE	PMS	R6	R12	R24	R48	R72	R96
0.0	21.20	111.00	125.00	133.00	142.00	0.0	0.0

TRSPC COMPUTED BY THE PROGRAM IS 0.300

LOSS DATA

LROPT	STRKR	DLTKR	RTIOL	ERAIN	STRKS	RTIOK	STRTL	CNSTL	ALSMX	RTIMP
0	0.0	0.0	1.00	0.0	0.0	1.00	2.00	0.10	0.0	0.0

UNIT HYDROGRAPH DATA
TP= 1.96 CP=0.63 NTA= 0

RECESSION DATA
STRTQ= -1.50 QRCSN= -0.05 RTIOR= 2.00

UNIT HYDROGRAPH 32 END-OF-PERIOD ORDINATES, LAG= 1.98 HOURS, CP= 0.63 VOL= 1.00

10.	33.	75.	114.	140.	152.	154.	139.	115.	95.
79.	63.	54.	45.	37.	31.	25.	21.	17.	14.
12.	10.	8.	7.	6.	5.	4.	3.	3.	2.
2.	1.								

SHEET 1 OF 12

0 DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	END-OF-PERIOD FLOW COMP Q	MO.DA	HR.MN	PERIOD	RAIN	EXCS	LOSS	COMP Q
									SUM	24.08	20.37	3.71	31505.
										(612.)(	517.)(	94.)(	892.12)

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HYDROGRAPH ROUTING

ROUTING SUBAREA A THROUGH HIGHLAND LAKE DAM

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
2	1	0	0	0	0	1	0	0

ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME	IOPT	IPMP	LSTR
0.0	0.0	0.0	1	1	0	0	0

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA	ISPRAT
1	0	0	0.0	0.0	0.0	-792.	-1

STAGE	792.00	792.50	793.00	794.00	795.00	796.00	797.00	798.00	799.00	799.50
FLOW	0.0	5.00	30.00	72.00	129.00	206.00	285.00	363.00	464.00	566.00

SURFACE AREA=	0.	118.	152.
CAPACITY=	0.	392.	1468.
ELEVATION=	782.	792.	800.

CREL	SPWID	COQW	EXPW	ELEVL	COQL	CAREA	EXPL
797.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DAM DATA

TOPEL	COQD	EXPD	DAMWID
797.0	3.1	1.5	470.

CREST LENGTH	330.	377.	463.	597.	730.	869.	1009.	1148.
AT OR BELOW ELEVATION	797.0	797.5	798.0	799.0	800.0	802.0	804.0	806.0

PEAK OUTFLOW IS 397. AT TIME 45.67 HOURS

PEAK OUTFLOW IS 213. AT TIME 46.33 HOURS

PEAK OUTFLOW IS 121. AT TIME 46.67 HOURS

PEAK OUTFLOW IS 51. AT TIME 47.00 HOURS

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HYDROGRAPH ROUTING

CHANNEL ROUTING SUBAREA A TO WOODWARD DAM

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
3	1	0	0	0	0	1	0	0

ROUTING DATA

RSVRS	CLOSS	AVG	IRES	ISAME	IOPT	IPMP	LSTR
0.0	0.0	0.0	1	1	0	0	0

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA	ISPRAT
1	0	0	0.0	0.0	0.0	-1.	0

NORMAL DEPTH CHANNEL ROUTING

JXL(1)	JXL(2)	JXL(3)	ELEVT	ELMAX	RLNTH	SEL
0.0800	0.0600	0.0300	767.0	810.0	460.	0.05200

CROSS SECTION COORDINATES--STA,ELEV,STA,ELEV--ETC

0.0 810.00 270.00 800.00 330.00 780.00 520.00 777.00 780.00 783.00
830.00 784.00 1340.00 800.00 1120.00 810.00

STORAGE	0.0	0.0	0.0	0.0	0.0	1.31	9.30	21.29	38.32	46.04
	60.58	73.42	91.13	107.72	125.17	143.39	163.73	183.76	204.00	225.49
OUTFLOW	0.0	0.0	0.0	0.0	0.0	832.42	12041.54	43849.09	90490.94	152046.00
	226726.44	314317.94	413623.00	525350.94	649085.13	783178.44	929473.69	1091091.00	1268320.00	1455945.00
STAGE	767.00	769.26	771.53	773.79	776.05	778.31	780.58	782.84	785.10	787.37
	789.63	791.89	794.16	796.42	798.68	800.94	803.21	805.47	807.73	810.00
FLOW	0.0	0.0	0.0	0.0	0.0	832.42	12041.54	43849.09	90490.94	152046.00
	226726.44	314317.94	413623.00	525350.94	649085.13	783178.44	929473.69	1091091.00	1268320.00	1455945.00

MAXIMUM STAGE IS 777.1

MAXIMUM STAGE IS 776.5

MAXIMUM STAGE IS 776.4

MAXIMUM STAGE IS 776.2

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SUB-AREA RUNOFF COMPUTATION

RUNOFF COMPUTATION FOR SUBAREA B

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
4	0	0	0	0	0	1	0	0

HYDROGRAPH DATA

IHYDG	IUHG	TAREA	SNAP	TRSDA	TRSPC	RATIO	ISMON	ISAME	LOCAL
1	1	0.72	0.0	0.72	0.0	0.0	0	0	0

PRECIP DATA

SPFE	PMS	R6	R12	R24	R48	R72	R96
0.0	21.20	111.00	123.00	133.00	142.00	0.0	0.0

TRSPC COMPUTED BY THE PROGRAM IS 0.300

LOSS DATA

LROPT	STRKR	DLTKR	RTIOL	ERAIN	STRKS	RTIOR	STRTL	CNSTL	ALSMX	RTIMP

0	0.0	0.0	1.00	0.0	0.0	1.00	1.00	0.10	0.0	0.0

UNIT HYDROGRAPH DATA
TP= 1.67 CP=0.63 NTA= 0

RECESSION DATA
STRTQ= -1.50 QRCSN= -0.05 RTIOR= 2.00

UNIT HYDROGRAPH 27 END-OF-PERIOD ORDINATES, LAG= 1.66 HOURS, CP= 0.63 VOL= 1.00

14.	55.	101.	147.	174.	174.	149.	119.	95.	75.
60.	48.	38.	30.	24.	19.	15.	12.	10.	8.
6.	5.	4.	3.	2.	2.	2.			

0
END-OF-PERIOD FLOW

MO.DA HR.MN PERIOD RAIN EXCS LOSS COMP Q MO.DA HR.MN PERIOD RAIN EXCS LOSS COMP Q

SUM 24.08 20.37 3.71 29134.
(612.)(517.)(94.)(824.98)

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COMBINE HYDROGRAPHS

COMBINED HYDROGRAPHS FOR SUBAREAS A AND B

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
5	2	0	0	0	0	1	0	0

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HYDROGRAPH ROUTING

ROUTING FOR WOODWARD DAM

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
6	1	0	0	0	0	1	0	0

ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME	IOPT	IPMP		LSTR
0.0	0.0	0.0	1	1	0	0		0

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA	ISPRAT
0	0	0	0.0	0.0	0.0	-757.	-1

STAGE	767.00	767.50	768.00	768.50	769.00	769.50	770.00
FLOW	0.0	29.30	96.00	185.00	308.00	465.00	632.00

SURFACE AREA=	8.	101.	215.
CAPACITY=	0.	1332.	3364.
ELEVATION=	738.	767.	780.

CREL	SPWID	COQW	EXPW	ELEVL	COQL	CAREA	EXPL
767.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DAM DATA

TOPEL	COQD	EXPD	DAMWID
769.7	3.1	1.5	744.

CREST LENGTH	0.	20.	69.	78.	239.	407.	596.	761.	826.	910.

ELEVATION	109.7	110.3	111.0	111.3	111.4	111.6	111.8	112.0	113.0	119.0

PEAK OUTFLOW IS 1084. AT TIME +3.67 HOURS

PEAK OUTFLOW IS 725. AT TIME +4.00 HOURS

PEAK OUTFLOW IS 422. AT TIME +4.00 HOURS

PEAK OUTFLOW IS 157. AT TIME +4.67 HOURS

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PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	AREA	PLAN	RATIOS APPLIED TO FLOWS RATIO 1 1.00	RATIO 2 0.75	RATIO 3 0.50	RATIO 4 0.25
HYDROGRAPH AT	1	0.73 (2.02)	1	1857. (52.59)	1393. (39.45)	929. (26.30)	464. (13.15)
ROUTED TO	2	0.73 (2.02)	1	397. (11.24)	213. (6.04)	121. (3.41)	51. (1.44)
ROUTED TO	3	0.73 (2.02)	1	397. (11.25)	213. (6.04)	121. (3.41)	51. (1.44)
HYDROGRAPH AT	4	0.72 (1.86)	1	1867. (52.86)	1400. (39.63)	933. (26.43)	467. (13.22)
2 COMBINED	5	1.45 (3.88)	1	1987. (56.26)	1481. (41.95)	983. (27.83)	484. (13.71)
ROUTED TO	6	1.45 (3.88)	1	1084. (30.71)	725. (20.52)	422. (11.94)	157. (4.45)

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 HIGHLAND LAKE DAM

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	792.00	797.00	797.00
STORAGE	392.	1032.	1032.
OUTFLOW	0.	285.	285.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	797.20	0.20	1060.	397.	4.00	45.67	0.0
0.75	796.09	0.0	937.	213.	0.0	46.33	0.0
0.50	794.85	0.0	744.	121.	0.0	46.67	0.0
0.25	793.49	0.0	572.	51.	0.0	47.00	0.0

PLAN 1 STATION 3

RATIO	MAXIMUM FLOW,CFS	MAXIMUM STAGE,FT	TIME HOURS
1.00	397.	777.1	45.67
0.75	213.	776.6	46.33
0.50	121.	776.4	46.67
0.25	51.	776.2	47.00

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 Woodward Dam

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	767.00	767.00	769.70
STORAGE	1332.	1332.	1933.
OUTFLOW	0.	0.	932.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	770.98	1.28	1755.	1084.	9.01	43.01	0.0
0.75	770.23	0.53	1679.	725.	5.01	44.00	0.0
0.50	769.36	0.0	1592.	422.	0.0	44.00	0.0
0.25	768.34	0.0	1475.	157.	0.0	44.01	0.0

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*********************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  26 FEB 79
  MOD UPDATE         04 JUL 79
*********************************
A1       NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS
A2       HYDROLOGIC AND HYDRAULIC ANALYSIS OF WOODWARD DAM
A3       DEWATERING ANALYSIS OF WOODWARD DAM
B    400       0       0       0       0       0       0       0       0       0
B1     5
J      1       1       1
J1   1.0
K      0       1                                  1
K1       INFLOW RUNOFF HYDROGRAPH TO DAM
M     -1            1.50             1.50                        1
N
N
N
N
N
N
N
N
N
N
N
N
N
N
N
N
N
N
N
N
N
N
N
N
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N
N
N
N
N
N
N
N
N
N
N
N
N
```

DEWATERING

SHEET 25 OF 38

```
K       1      2                                  1
K1          DEWATERING WOODWARD DAM
Y                                     1       1
Y1      1                                              -767.0      -1
Y4 738.0   739.0   740.6   742.0   744.0   746.0   748.0   750.0   754.0   756.0
Y4 762.0   766.0   767.0
Y5      0    4.73    4.81    4.98    5.15    5.31    5.46    5.61    5.90    6.17
Y5  6.43   6.57    6.75
$A  8.00 101.26   218.8
$E   733    737     780
$$ 767.0
$D 769.7   3.00     1.5     744
K     99
```

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**********************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
 LAST MODIFICATION  26 FEB 79
  MOD UPDATE         04 JUL 79
**********************************

RUN  DATE 02/11/81
     TIME    11.10
```

NATIONAL PROGRAM FOR INSPECTION OF NON-FEDERAL DAMS
HYDROLOGIC AND HYDRAULIC ANALYSIS OF WOODWARD DAM
DEWATERING ANALYSIS OF WOODWARD DAM

JOB SPECIFICATION

NQ	NHR	NMIN	IDAY	IHR	IMIN	METRC	IPLT	IPRT	NSTAN
400	0	0	0	0	0	0	0	0	0

JOPER	NWT	LROPT	TRACE	
5	0	0	0	0

MULTI-PLAN ANALYSES TO BE PERFORMED
NPLAN= 1 NRTIO= 1 LRTIO= 1

RTIOS= 1.00

********** ********** ********** ********** **********

SUB-AREA RUNOFF COMPUTATION

NULL RUNOFF HYDROGRAPH TO DAM

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
1	0	0	0	0	0	1	0	0

HYDROGRAPH DATA

IHYDG	IUHG	TAREA	SNAP	TRSDA	TRSPC	RATIO	ISNOW	ISAME	LOCAL
-1	0	1.50	0.0	1.50	0.0	0.0	0	1	0

INPUT HYDROGRAPH

0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

	PEAK	10-DAY	30-DAY	90-DAY	TOTAL VOLUME
CFS	0.	0.	0.	0.	0.
CMS	0.	0.	0.	0.	0.
INCHES		0.0	0.0	0.0	0.0
MM		0.0	0.0	0.0	0.0
AC-FT		0.	0.	0.	0.
THOUS CU M		0.	0.	0.	0.

HYDROGRAPH AT STA 1 FOR PLAN 1, RTIO 1

.	0.	0.	0.	0.	0.	0.	0.	0.	0.
.	0.	0.	0.	0.	0.	0.	0.	0.	0.
.	0.	0.	0.	0.	0.	0.	0.	0.	0.
.	0.	0.	0.	0.	0.	0.	0.	0.	0.
.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

	PEAK	10-DAY	30-DAY	90-DAY	TOTAL VOLUME
CFS	0.	0.	0.	0.	0.
CMS	0.	0.	0.	0.	0.
INCHES		0.0	0.0	0.0	0.0
MM		0.0	0.0	0.0	0.0
AC-FT		0.	0.	0.	0.
THOUS CU M		0.	0.	0.	0.

********** ********** ********** ********** **********

HYDROGRAPH ROUTING

DEV TERING WOODWARD DAM

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
2	1	0	0	0	0	1	0	0

ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME	IOPT	IPMP	LSTR
0.0	0.0	0.0	1	1	0	0	0

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA	ISPRAT
1	0	0	0.0	0.0	0.0	-767.	-1

STAGE	138.00	139.00	140.00	142.00	144.00	146.00	148.00	150.00	154.00	158.00
	162.00	166.00	167.00							
FLOW	0.0	4.73	4.81	4.98	5.15	5.31	5.48	5.64	5.97	6.31
	6.43	6.89	6.75							

SURFACE AREA= 8. 101. 219.

CAPACITY= 0. 1332. 3304.

ELEVATION= 138. 167. 180.

CREL	SPWID	COQW	EXPW	ELEVL	COQL	CAREA	EXPL
767.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DAM DATA

TOPEL	COQD	EXPD	DAMWID
769.7	3.1	1.5	744.

STATION 2, PLAN 1, RATIO 1

END-OF-PERIOD HYDROGRAPH ORDINATES

MO.DA	HR.MN	PERIOD	HOURS	INFLOW	OUTFLOW	STORAGE	STAGE
1.01	8.00	1	8.00	0.	1.	1328.	767.0
1.01	16.00	2	16.00	0.	1.	1325.	766.9
1.02	0.0	3	24.00	0.	1.	1322.	766.9
1.02	8.00	4	32.00	0.	1.	1319.	766.8
1.02	16.00	5	40.00	0.	1.	1316.	766.8
1.03	0.0	6	48.00	0.	1.	1313.	766.7
1.03	8.00	7	56.00	0.	1.	1310.	766.7

1.33	16.00	8	64.00	0.	1.	1296.	100.0
1.34	0.0	9	72.00	0.	1.	1292.	100.0
1.34	8.00	10	80.00	0.	1.	1287.	100.0
1.34	16.00	11	88.00	0.	1.	1283.	100.0
1.35	0.0	12	96.00	0.	1.	1279.	100.0
1.35	8.00	13	104.00	0.	1.	1274.	100.0
1.35	16.00	14	112.00	0.	1.	1270.	100.0
1.36	0.0	15	120.00	0.	1.	1265.	100.0
1.36	8.00	16	128.00	0.	1.	1261.	100.0
1.36	16.00	17	136.00	0.	1.	1256.	100.0
1.37	0.0	18	144.00	0.	1.	1252.	100.0
1.37	8.00	19	152.00	0.	1.	1248.	100.1
1.37	16.00	20	160.00	0.	1.	1243.	100.1
1.38	0.0	21	168.00	0.	1.	1239.	100.1
1.38	8.00	22	176.00	0.	1.	1234.	100.0
1.38	16.00	23	184.00	0.	1.	1230.	100.0
1.39	0.0	24	192.00	0.	1.	1225.	100.0
1.39	8.00	25	200.00	0.	1.	1221.	100.0
1.39	16.00	26	208.00	0.	1.	1216.	100.0
1.40	0.0	27	216.00	0.	1.	1212.	100.0
1.40	8.00	28	224.00	0.	1.	1208.	100.1
1.40	16.00	29	232.00	0.	1.	1203.	100.1
1.41	0.0	30	240.00	0.	1.	1199.	100.0
1.41	8.00	31	248.00	0.	1.	1194.	100.0
1.41	16.00	32	256.00	0.	1.	1190.	100.0
1.42	0.0	33	264.00	0.	1.	1186.	100.0
1.42	8.00	34	272.00	0.	1.	1181.	100.0
1.42	16.00	35	280.00	0.	1.	1177.	100.0
1.43	0.0	36	288.00	0.	1.	1172.	100.0
1.43	8.00	37	296.00	0.	1.	1168.	100.0
1.43	16.00	38	304.00	0.	1.	1164.	100.0
1.44	0.0	39	312.00	0.	1.	1159.	100.0
1.44	8.00	40	320.00	0.	1.	1155.	100.0
1.44	16.00	41	328.00	0.	1.	1150.	100.1
1.45	0.0	42	336.00	0.	1.	1146.	100.1
1.45	8.00	43	344.00	0.	1.	1142.	100.0
1.45	16.00	44	352.00	0.	1.	1137.	100.0
1.46	0.0	45	360.00	0.	1.	1133.	100.0
1.46	8.00	46	368.00	0.	1.	1128.	100.0
1.46	16.00	47	376.00	0.	1.	1124.	100.0
1.47	0.0	48	384.00	0.	1.	1120.	100.0
1.47	8.00	49	392.00	0.	1.	1115.	100.1
1.47	16.00	50	400.00	0.	1.	1111.	100.1
1.48	0.0	51	408.00	0.	1.	1107.	100.0
1.48	8.00	52	416.00	0.	1.	1102.	100.0
1.48	16.00	53	424.00	0.	1.	1098.	100.0
1.49	0.0	54	432.00	0.	1.	1093.	100.0
1.49	8.00	55	440.00	0.	1.	1089.	100.0
1.49	16.00	56	448.00	0.	1.	1085.	100.0
1.50	0.0	57	456.00	0.	1.	1080.	100.0
1.50	8.00	58	464.00	0.	1.	1076.	100.0
1.50	16.00	59	472.00	0.	1.	1072.	100.0
1.51	0.0	60	480.00	0.	1.	1067.	100.0
1.51	8.00	61	488.00	0.	1.	1063.	100.1
1.51	16.00	62	496.00	0.	1.	1059.	100.1
1.52	0.0	63	504.00	0.	1.	1054.	100.0
1.52	8.00	64	512.00	0.	1.	1050.	100.0
1.52	16.00	65	520.00	0.	1.	1046.	100.0
1.53	0.0	66	528.00	0.	1.	1041.	100.0
1.53	8.00	67	536.00	0.	1.	1037.	100.0
1.53	16.00	68	544.00	0.	1.	1033.	100.0
1.54	0.0	69	552.00	0.	1.	1028.	100.1
1.54	8.00	70	560.00	0.	1.	1024.	100.1
1.54	16.00	71	568.00	0.	1.	1020.	100.0
1.55	0.0	72	576.00	0.	1.	1015.	100.0
1.55	8.00	73	584.00	0.	1.	1011.	100.0

1.25	16.00	74	592.00	0.	1.	1007.	103.9
1.26	0.0	75	600.00	0.	1.	1002.	103.9
1.26	8.00	76	608.00	0.	1.	998.	103.9
1.26	16.00	77	616.00	0.	1.	994.	103.9
1.27	0.0	78	624.00	0.	1.	989.	103.9
1.27	8.00	79	632.00	0.	1.	985.	103.8
1.27	16.00	80	640.00	0.	1.	981.	103.8
1.28	0.0	81	648.00	0.	1.	976.	103.8
1.28	8.00	82	656.00	0.	0.	972.	103.8
1.28	16.00	83	664.00	0.	0.	968.	103.8
1.29	0.0	84	672.00	0.	0.	964.	103.8
1.29	8.00	85	680.00	0.	0.	959.	103.8
1.29	16.00	86	688.00	0.	0.	955.	103.9
1.30	0.0	87	696.00	0.	0.	951.	103.8
1.30	8.00	88	704.00	0.	0.	946.	103.8
1.30	16.00	89	712.00	0.	0.	942.	103.8
1.31	0.0	90	720.00	0.	0.	938.	103.8
1.31	8.00	91	728.00	0.	0.	933.	103.8
1.31	16.00	92	736.00	0.	0.	929.	103.9
2.01	0.0	93	744.00	0.	0.	925.	103.9
2.01	8.00	94	752.00	0.	0.	921.	103.9
2.01	16.00	95	760.00	0.	0.	916.	103.9
2.02	0.0	96	768.00	0.	0.	912.	103.9
2.02	8.00	97	776.00	0.	0.	908.	103.9
2.02	16.00	98	784.00	0.	0.	904.	103.9
2.03	0.0	99	792.00	0.	0.	899.	103.9
2.03	8.00	100	800.00	0.	0.	895.	103.9
2.03	16.00	101	808.00	0.	0.	891.	103.9
2.04	0.0	102	816.00	0.	0.	887.	103.9
2.04	8.00	103	824.00	0.	0.	882.	103.8
2.04	16.00	104	832.00	0.	0.	878.	103.9
2.05	0.0	105	840.00	0.	0.	874.	103.8
2.05	8.00	106	848.00	0.	0.	870.	103.8
2.05	16.00	107	856.00	0.	0.	865.	103.9
2.06	0.0	108	864.00	0.	0.	861.	103.9
2.06	8.00	109	872.00	0.	0.	857.	103.8
2.06	16.00	110	880.00	0.	0.	853.	103.8
2.07	0.0	111	888.00	0.	0.	848.	103.9
2.07	8.00	112	896.00	0.	0.	844.	103.9
2.07	16.00	113	904.00	0.	0.	840.	103.9
2.08	0.0	114	912.00	0.	0.	836.	103.9
2.08	8.00	115	920.00	0.	0.	831.	103.9
2.08	16.00	116	928.00	0.	0.	827.	103.9
2.09	0.0	117	936.00	0.	0.	823.	103.9
2.09	8.00	118	944.00	0.	0.	819.	103.9
2.09	16.00	119	952.00	0.	0.	815.	103.9
2.10	0.0	120	960.00	0.	0.	810.	103.9
2.10	8.00	121	968.00	0.	0.	806.	103.9
2.10	16.00	122	976.00	0.	0.	802.	103.9
2.11	0.0	123	984.00	0.	0.	798.	103.8
2.11	8.00	124	992.00	0.	0.	793.	103.8
2.11	16.00	125	1000.00	0.	0.	789.	103.8
2.12	0.0	126	1008.00	0.	0.	785.	103.8
2.12	8.00	127	1016.00	0.	0.	781.	103.8
2.12	16.00	128	1024.00	0.	0.	777.	103.9
2.13	0.0	129	1032.00	0.	0.	772.	103.9
2.13	8.00	130	1040.00	0.	0.	768.	103.8
2.13	16.00	131	1048.00	0.	0.	764.	103.9
2.14	0.0	132	1056.00	0.	0.	760.	103.9
2.14	8.00	133	1064.00	0.	0.	756.	103.8
2.14	16.00	134	1072.00	0.	0.	752.	103.8
2.15	0.0	135	1080.00	0.	0.	747.	103.8
2.15	8.00	136	1088.00	0.	0.	743.	103.8
2.15	16.00	137	1096.00	0.	0.	739.	103.8
2.16	0.0	138	1104.00	0.	0.	735.	103.9

2.16	16.00	1401120.00	0.	0.	727.	159.8
2.17	0.0	1411128.00	0.	0.	722.	159.8
2.17	8.00	1421136.00	0.	0.	718.	159.7
2.17	16.00	1431144.00	0.	0.	714.	159.6
2.18	0.0	1441152.00	0.	0.	710.	159.6
2.18	8.00	1451160.00	0.	0.	706.	159.5
2.18	16.00	1461168.00	0	0.	702.	159.4
2.19	0.0	1471176.00	0.	0.	698.	159.4
2.19	8.00	1481184.00	0.	0.	693.	159.3
2.19	16.00	1491192.00	0.	0.	689.	159.3
2.20	0.0	1501200.00	0.	0.	685.	159.2
2.20	8.00	1511208.00	0.	0.	681.	159.1
2.20	16.00	1521216.00	0.	0.	677.	159.1
2.21	0.0	1531224.00	0.	0.	673.	159.0
2.21	8.00	1541232.00	0.	0.	669.	158.9
2.21	16.00	1551240.00	0.	0.	664.	158.9
2.22	0.0	1561248.00	0.	0.	660.	158.8
2.22	8.00	1571256.00	0.	0.	656.	158.8
2.22	16.00	1581264.00	0.	0.	652.	158.7
2.23	0.0	1591272.00	0.	0.	648.	158.6
2.23	8.00	1601280.00	0.	0.	644.	158.6
2.23	16.00	1611288.00	0.	0.	640.	158.5
2.24	0.0	1621296.00	0.	0.	636.	158.4
2.24	8.00	1631304.00	0.	0.	632.	158.4
2.24	16.00	1641312.00	0.	0.	627.	158.3
2.25	0.0	1651320.00	0.	0.	623.	158.2
2.25	8.00	1661328.00	0.	0.	619.	158.2
2.25	16.00	1671336.00	0.	0.	615.	158.1
2.26	0.0	1681344.00	0.	0.	611.	158.0
2.26	8.00	1691352.00	0.	0.	607.	158.0
2.26	16.00	1701360.00	0.	0.	603.	157.9
2.27	0.0	1711368.00	0.	0.	599.	157.8
2.27	8.00	1721376.00	0.	0.	595.	157.8
2.27	16.00	1731384.00	0.	0.	591.	157.7
2.28	0.0	1741392.00	0.	0.	587.	157.6
2.28	8.00	1751400.00	0.	0.	583.	157.6
2.28	16.00	1761408.00	0.	0.	579.	157.5
2.29	0.0	1771416.00	0.	0.	575.	157.4
2.29	8.00	1781424.00	0.	0.	570.	157.4
2.29	16.00	1791432.00	0.	0.	566.	157.3
3.01	0.0	1801440.00	0.	0.	562.	157.2
3.01	8.00	1811448.00	0.	0.	558.	157.2
3.01	16.00	1821456.00	0.	0.	554.	157.1
3.02	0.0	1831464.00	0.	0.	550.	157.0
3.02	8.00	1841472.00	0.	0.	546.	156.9
3.02	16.00	1851480.00	0.	0.	542.	156.9
3.03	0.0	1861488.00	0.	0.	538.	156.8
3.03	8.00	1871496.00	0.	0.	534.	156.7
3.03	16.00	1881504.00	0.	0.	530.	156.7
3.04	0.0	1891512.00	0.	0.	526.	156.6
3.04	8.00	1901520.00	0.	0.	522.	156.5
3.04	16.00	1911528.00	0.	0.	518.	156.4
3.05	0.0	1921536.00	0.	0.	514.	156.4
3.05	8.00	1931544.00	0.	0.	510.	156.3
3.05	16.00	1941552.00	0.	0.	506.	156.2
3.06	0.0	1951560.00	0.	0.	502.	156.1
3.06	8.00	1961568.00	0.	0.	498.	156.1
3.06	16.00	1971576.00	0.	0.	494.	156.0
3.07	0.0	1981584.00	0.	0.	490.	155.9
3.07	8.00	1991592.00	0.	0.	486.	155.8
3.07	16.00	2001600.00	0.	0.	482.	155.8
3.08	0.0	2011608.00	0.	0.	478.	155.7
3.08	8.00	2021616.00	0.	0.	474.	155.6
3.08	16.00	2031624.00	0.	0.	470.	155.5
3.09	0.0	2041632.00	0.	0.	466.	155.5

3.09	16.00	2061648.00	0.	0.	458.	155.3
3.10	0.0	2071656.00	0.	0.	454.	155.2
3.10	8.00	2081664.00	0.	0.	450.	155.2
3.10	16.00	2091672.00	0.	0.	446.	155.1
3.11	0.0	2101680.00	0.	0.	442.	155.0
3.11	8.00	2111688.00	0.	0.	438.	154.9
3.11	16.00	2121696.00	0.	0.	433.	154.8
3.12	0.0	2131704.00	0.	0.	429.	154.8
3.12	8.00	2141712.00	0.	0.	425.	154.7
3.12	16.00	2151720.00	0.	0.	421.	154.6
3.13	0.0	2161728.00	0.	0.	417.	154.5
3.13	8.00	2171736.00	0.	0.	413.	154.4
3.13	16.00	2181744.00	0.	0.	411.	154.4
3.14	0.0	2191752.00	0.	0.	407.	154.3
3.14	8.00	2201760.00	0.	0.	403.	154.2
3.14	16.00	2211768.00	0.	0.	399.	154.1
3.15	0.0	2221776.00	0.	0.	395.	154.0
3.15	8.00	2231784.00	0.	0.	391.	153.9
3.15	16.00	2241792.00	0.	0.	388.	153.9
3.16	0.0	2251800.00	0.	0.	384.	153.8
3.16	8.00	2261808.00	0.	0.	380.	153.7
3.16	16.00	2271816.00	0.	0.	376.	153.6
3.17	0.0	2281824.00	0.	0.	372.	153.5
3.17	8.00	2291832.00	0.	0.	368.	153.4
3.17	16.00	2301840.00	0.	0.	364.	153.3
3.18	0.0	2311848.00	0.	0.	360.	153.3
3.18	8.00	2321856.00	0.	0.	357.	153.2
3.18	16.00	2331864.00	0.	0.	353.	153.1
3.19	0.0	2341872.00	0.	0.	349.	153.0
3.19	8.00	2351880.00	0.	0.	345.	152.9
3.19	16.00	2361888.00	0.	0.	341.	152.8
3.20	0.0	2371896.00	0.	0.	337.	152.7
3.20	8.00	2381904.00	0.	0.	334.	152.6
3.20	16.00	2391912.00	0.	0.	330.	152.5
3.21	0.0	2401920.00	0.	0.	326.	152.4
3.21	8.00	2411928.00	0.	0.	322.	152.3
3.21	16.00	2421936.00	0.	0.	318.	152.3
3.22	0.0	2431944.00	0.	0.	314.	152.2
3.22	8.00	2441952.00	0.	0.	311.	152.1
3.22	16.00	2451960.00	0.	0.	307.	152.0
3.23	0.0	2461968.00	0.	0.	303.	151.9
3.23	8.00	2471976.00	0.	0.	299.	151.8
3.23	16.00	2481984.00	0.	0.	295.	151.7
3.24	0.0	2491992.00	0.	0.	292.	151.6
3.24	8.00	2502000.00	0.	0.	288.	151.5
3.24	16.00	2512008.00	0.	0.	284.	151.4
3.25	0.0	2522016.00	0.	0.	280.	151.3
3.25	8.00	2532024.00	0.	0.	277.	151.2
3.25	16.00	2542032.00	0.	0.	273.	151.1
3.26	0.0	2552040.00	0.	0.	269.	151.0
3.26	8.00	2562048.00	0.	0.	265.	150.9
3.26	16.00	2572056.00	0.	0.	262.	150.8
3.27	0.0	2582064.00	0.	0.	258.	150.7
3.27	8.00	2592072.00	0.	0.	254.	150.6
3.27	16.00	2602080.00	0.	0.	250.	150.5
3.28	0.0	2612088.00	0.	0.	247.	150.4
3.28	8.00	2622096.00	0.	0.	243.	150.3
3.28	16.00	2632104.00	0.	0.	239.	150.2
3.29	0.0	2642112.00	0.	0.	235.	150.0
3.29	8.00	2652120.00	0.	0.	232.	149.9
3.29	16.00	2662128.00	0.	0.	228.	149.8
3.30	0.0	2672136.00	0.	0.	224.	149.7
3.30	8.00	2682144.00	0.	0.	221.	149.6
3.30	16.00	2692152.00	0.	0.	217.	149.5
3.31	0.0	2702160.00	0.	0.	213.	149.4

4.31	16.00	2722176.00	0.	0.	208.	149.1
4.32	0.0	2732184.00	0.	0.	202.	149.0
4.32	8.00	2742192.00	0.	0.	197.	148.9
4.32	16.00	2752200.00	0.	0.	195.	148.8
4.33	0.0	2762208.00	0.	0.	191.	148.7
4.33	8.00	2772216.00	0.	0.	188.	148.6
4.33	16.00	2782224.00	0.	0.	184.	148.4
4.34	0.0	2792232.00	0.	0.	180.	148.3
4.34	8.00	2802240.00	0.	0.	177.	148.2
4.34	16.00	2812248.00	0.	0.	173.	148.1
4.35	0.0	2822256.00	0.	0.	170.	147.9
4.35	8.00	2832264.00	0.	0.	168.	147.8
4.35	16.00	2842272.00	0.	0.	164.	147.7
4.36	0.0	2852280.00	0.	0.	159.	147.5
4.36	8.00	2862288.00	0.	0.	159.	147.4
4.36	16.00	2872296.00	0.	0.	152.	147.3
4.37	0.0	2882304.00	0.	0.	149.	147.1
4.37	8.00	2892312.00	0.	0.	149.	147.0
4.37	16.00	2902320.00	0.	0.	141.	146.9
4.38	0.0	2912328.00	0.	0.	137.	146.7
4.38	8.00	2922336.00	0.	0.	139.	146.6
4.38	16.00	2932344.00	0.	0.	130.	146.4
4.39	0.0	2942352.00	0.	0.	127.	146.3
4.39	8.00	2952360.00	0.	0.	123.	146.1
4.39	16.00	2962368.00	0.	0.	120.	146.0
4.40	0.0	2972376.00	0.	0.	118.	145.8
4.40	8.00	2982384.00	0.	0.	113.	145.7
4.40	16.00	2992392.00	0.	0.	109.	145.5
4.41	0.0	3002400.00	0.	0.	106.	145.4
4.41	8.00	3012408.00	0.	0.	104.	145.2
4.41	16.00	3022416.00	0.	0.	99.	145.0
4.42	0.0	3032424.00	0.	0.	95.	144.9
4.42	8.00	3042432.00	0.	0.	92.	144.7
4.42	16.00	3052440.00	0.	0.	88.	144.5
4.43	0.0	3062448.00	0.	0.	85.	144.4
4.43	8.00	3072456.00	0.	0.	82.	144.2
4.43	16.00	3082464.00	0.	0.	78.	144.0
4.44	0.0	3092472.00	0.	0.	75.	143.8
4.44	8.00	3102480.00	0.	0.	71.	143.6
4.44	16.00	3112488.00	0.	0.	68.	143.4
4.45	0.0	3122496.00	0.	0.	65.	143.2
4.45	8.00	3132504.00	0.	0.	61.	143.0
4.45	16.00	3142512.00	0.	0.	58.	142.8
4.46	0.0	3152520.00	0.	0.	55.	142.6
4.46	8.00	3162528.00	0.	0.	51.	142.4
4.46	16.00	3172536.00	0.	0.	48.	142.2
4.47	0.0	3182544.00	0.	0.	45.	142.0
4.47	8.00	3192552.00	0.	0.	41.	141.8
4.47	16.00	3202560.00	0.	0.	38.	141.5
4.48	0.0	3212568.00	0.	0.	35.	141.3
4.48	8.00	3222576.00	0.	0.	32.	141.0
4.48	16.00	3232584.00	0.	0.	28.	140.8
4.49	0.0	3242592.00	0.	0.	25.	140.5
4.49	8.00	3252600.00	0.	0.	22.	140.4
4.49	16.00	3262608.00	0.	0.	19.	140.0
4.50	0.0	3272616.00	0.	0.	16.	139.7
4.50	8.00	3282624.00	0.	0.	12.	139.4
4.50	16.00	3292632.00	0.	0.	9.	139.0
4.51	0.0	3302640.00	0.	0.	6.	138.8
4.51	8.00	3312648.00	0.	0.	4.	138.5
4.51	16.00	3322656.00	0.	2.	3.	138.4
4.52	0.0	3332664.00	0.	1.	2.	138.3
4.52	8.00	3342672.00	0.	1.	1.	138.2
4.52	16.00	3352680.00	0.	1.	1.	138.1
4.53	0.0	3362688.00	0.	0.	1.	138.1

SHEET 34 OF 38

4.22	16.00	3382704.00	0.	0.	0.	130.0
4.23	0.0	3392712.00	0.	0.	0.	130.0
4.23	8.00	3402720.00	0.	0.	0.	130.0
4.23	16.00	3412728.00	0.	0.	0.	130.0
4.24	0.0	3422736.00	0.	0.	0.	130.0
4.24	8.00	3432744.00	0.	0.	0.	130.0
4.24	16.00	3442752.00	0.	0.	0.	130.0
4.25	0.0	3452760.00	0.	0.	0.	130.0
4.25	8.00	3462768.00	0.	0.	0.	130.0
4.25	16.00	3472776.00	0.	0.	0.	130.0
4.26	0.0	3482784.00	0.	0.	0.	130.0
4.26	8.00	3492792.00	0.	0.	0.	130.0
4.26	16.00	3502800.00	0.	0.	0.	130.0
4.27	0.0	3512808.00	0.	0.	0.	130.0
4.27	8.00	3522816.00	0.	0.	0.	130.0
4.27	16.00	3532824.00	0.	0.	0.	130.0
4.28	0.0	3542832.00	0.	0.	0.	130.0
4.28	8.00	3552840.00	0.	0.	0.	130.0
4.28	16.00	3562848.00	0.	0.	0.	130.0
4.29	0.0	3572856.00	0.	0.	0.	130.0
4.29	8.00	3582864.00	0.	0.	0.	130.0
4.29	16.00	3592872.00	0.	0.	0.	130.0
4.30	0.0	3602880.00	0.	0.	0.	130.0
4.30	8.00	3612888.00	0.	0.	0.	130.0
4.30	16.00	3622896.00	0.	0.	0.	130.0
5.01	0.0	3632904.00	0.	0.	0.	130.0
5.01	8.00	3642912.00	0.	0.	0.	130.0
5.01	16.00	3652920.00	0.	0.	0.	130.0
5.02	0.0	3662928.00	0.	0.	0.	130.0
5.02	8.00	3672936.00	0.	0.	0.	130.0
5.02	16.00	3682944.00	0.	0.	0.	130.0
5.03	0.0	3692952.00	0.	0.	0.	130.0
5.03	8.00	3702960.00	0.	0.	0.	130.0
5.03	16.00	3712968.00	0.	0.	0.	130.0
5.04	0.0	3722976.00	0.	0.	0.	130.0
5.04	8.00	3732984.00	0.	0.	0.	130.0
5.04	16.00	3742992.00	0.	0.	0.	130.0
5.05	0.0	3753000.00	0.	0.	0.	130.0
5.05	8.00	3763008.00	0.	0.	0.	130.0
5.05	16.00	3773016.00	0.	0.	0.	130.0
5.06	0.0	3783024.00	0.	0.	0.	130.0
5.06	8.00	3793032.00	0.	0.	0.	130.0
5.06	16.00	3803040.00	0.	0.	0.	130.0
5.07	0.0	3813048.00	0.	0.	0.	130.0
5.07	8.00	3823056.00	0.	0.	0.	130.0
5.07	16.00	3833064.00	0.	0.	0.	130.0
5.08	0.0	3843072.00	0.	0.	0.	130.0
5.08	8.00	3853080.00	0.	0.	0.	130.0
5.08	16.00	3863088.00	0.	0.	0.	130.0
5.09	0.0	3873096.00	0.	0.	0.	130.0
5.09	8.00	3883104.00	0.	0.	0.	130.0
5.09	16.00	3893112.00	0.	0.	0.	130.0
5.10	0.0	3903120.00	0.	0.	0.	130.0
5.10	8.00	3913128.00	0.	0.	0.	130.0
5.10	16.00	3923136.00	0.	0.	0.	130.0
5.11	0.0	3933144.00	0.	0.	0.	130.0
5.11	8.00	3943152.00	0.	0.	0.	130.0
5.11	16.00	3953160.00	0.	0.	0.	130.0
5.12	0.0	3963168.00	0.	0.	0.	130.0
5.12	8.00	3973176.00	0.	0.	0.	130.0
5.12	16.00	3983184.00	0.	0.	0.	130.0
5.13	0.0	3993192.00	0.	0.	0.	130.0
5.13	8.00	4003200.00	0.	0.	0.	130.0

PEAK OUTFLOW IS 0. AT TIME 0.0 HOURS

	PEAK	10-DAY	30-DAY	90-DAY	TOTAL VOLUME
CFS	7.	7.	7.	0.	2307.
CMS	0.	0.	0.	0.	57.
INCHES		1.66	4.92	13.97	18.57
MM		42.26	125.03	354.91	471.93
AC-FT		135.	394.	1111.	1527.
THOUS CU M		164.	485.	1370.	1856.

********** ********** ********** ********** **********

SHEET 30 OF 35

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	AREA	PLAN	RATIO 1
				1.00
HYDROGRAPH AT	1	1.55	1	0.
		(3.88)	(	0.0) (
ROUTED TO	2	1.55	1	1.
		(3.88)	(	0.197) (

RATIOS APPLIED TO FLOWS

SHEET 37 OF 38

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	767.00	767.00	767.70
STORAGE	1332.	1332.	1833.
OUTFLOW	1.	1.	1.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	766.96	0.0	1332.	1.	0.0	0.0	0.0

APPENDIX D

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REFERENCES

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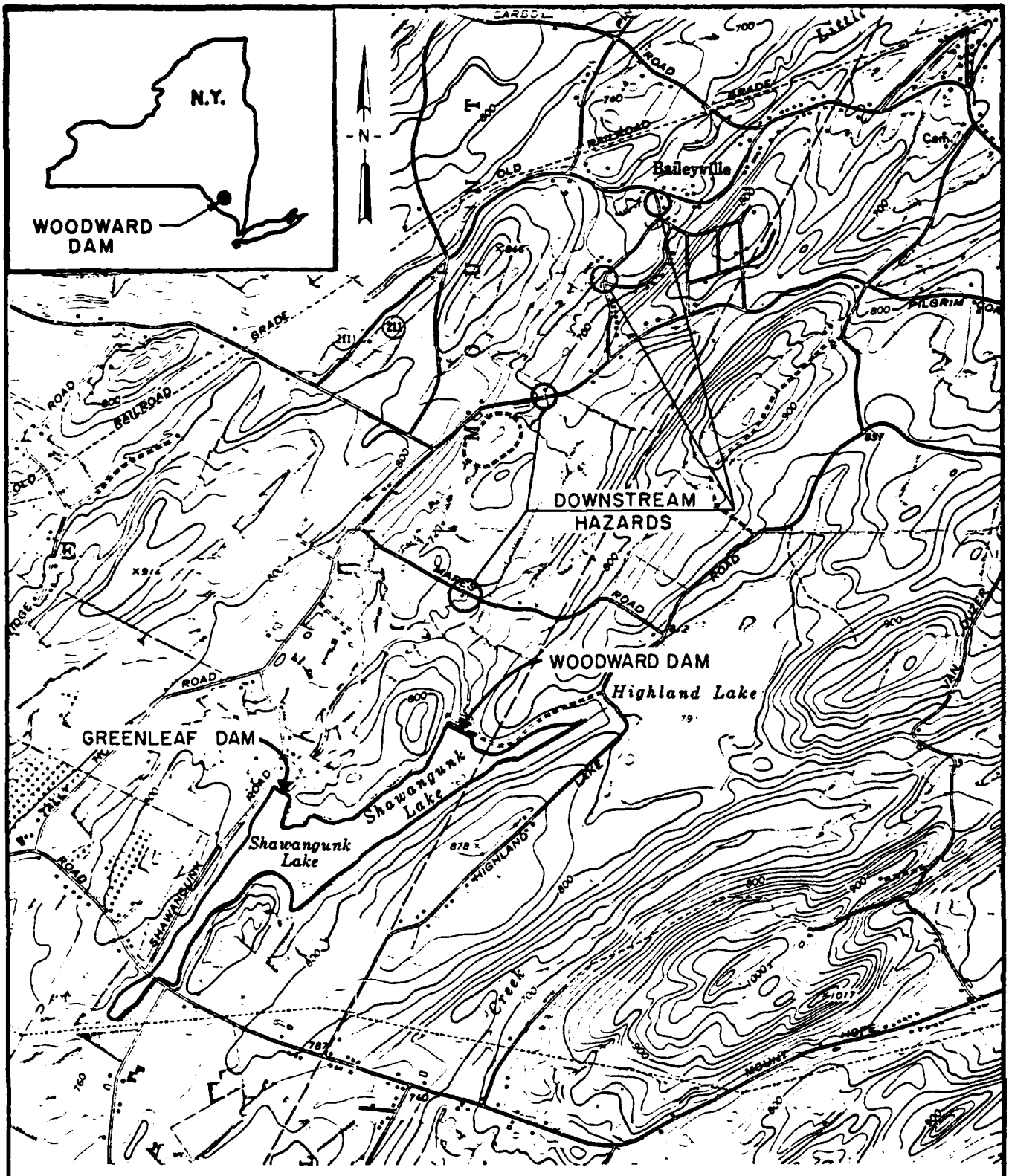
APPENDIX E

DRAWINGS

AD-A105 768 BAKER (MICHAEL) JR INC BEAVER PA F/G 13/13
NATIONAL DAM SAFETY PROGRAM. WOODWARD DAM (INVENTORY NUMBER NY --ETC(U)
JUN 81 G KESTER DACW51-81-C-0010
UNCLASSIFIED NL

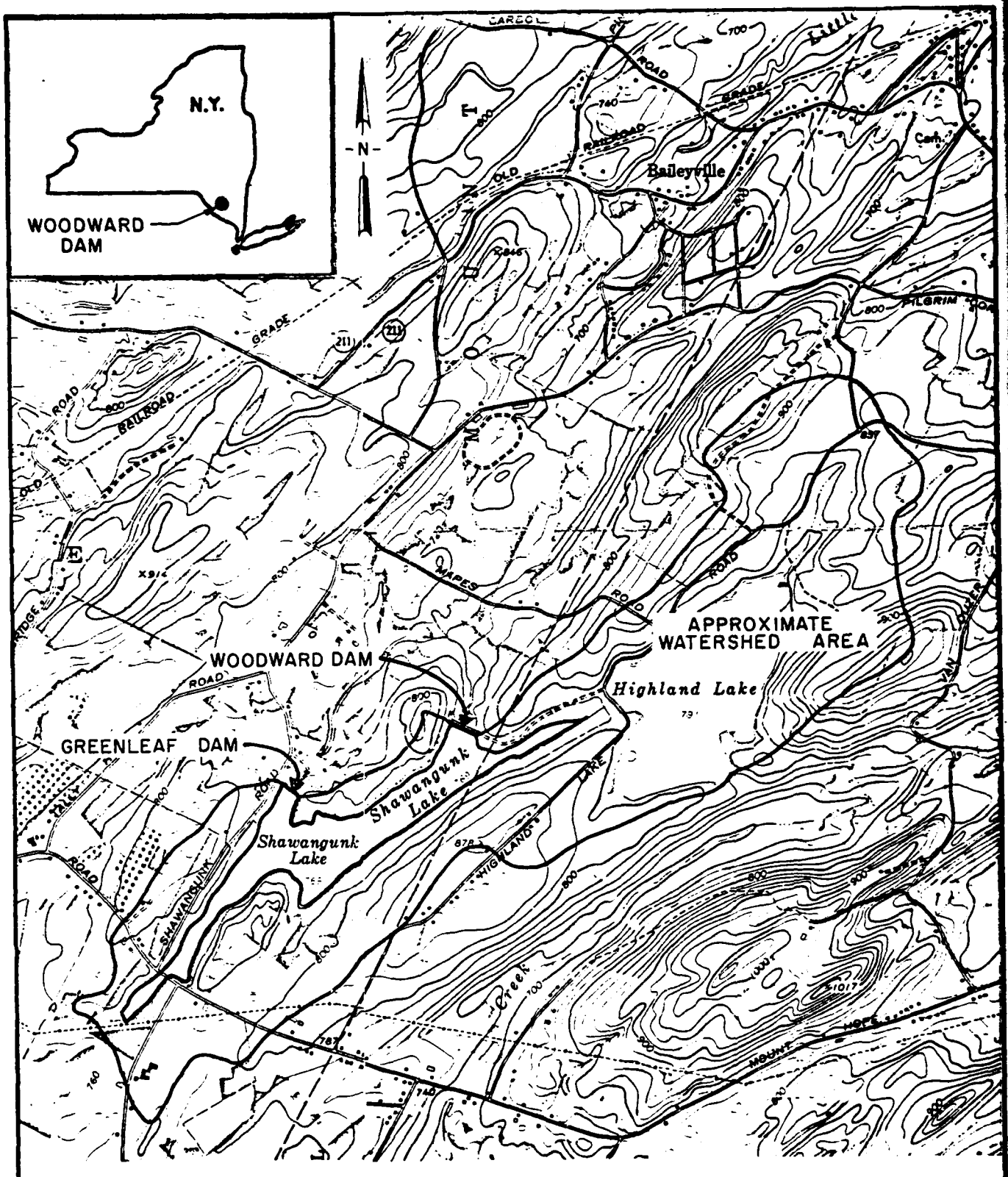
END
DATE FILMED
DTIC

CONTENTS



REFERENCES:
1. U.S.G.S. 7.5' MIDDLETOWN, N.Y. QUADRANGLE. 1969
2. U.S.G.S. 7.5' OTISVILLE, N.Y. QUADRANGLE. PHOTOINSPECTED 1976

LOCATION PLAN
WOODWARD DAM



REFERENCES:
1. U.S.G.S. 7.5 MIDDLETOWN, N.Y. QUADRANGLE. 1969
2. U.S.G.S. 7.5 OTISVILLE, N.Y. QUADRANGLE. PHOTOINSPECTED 1976

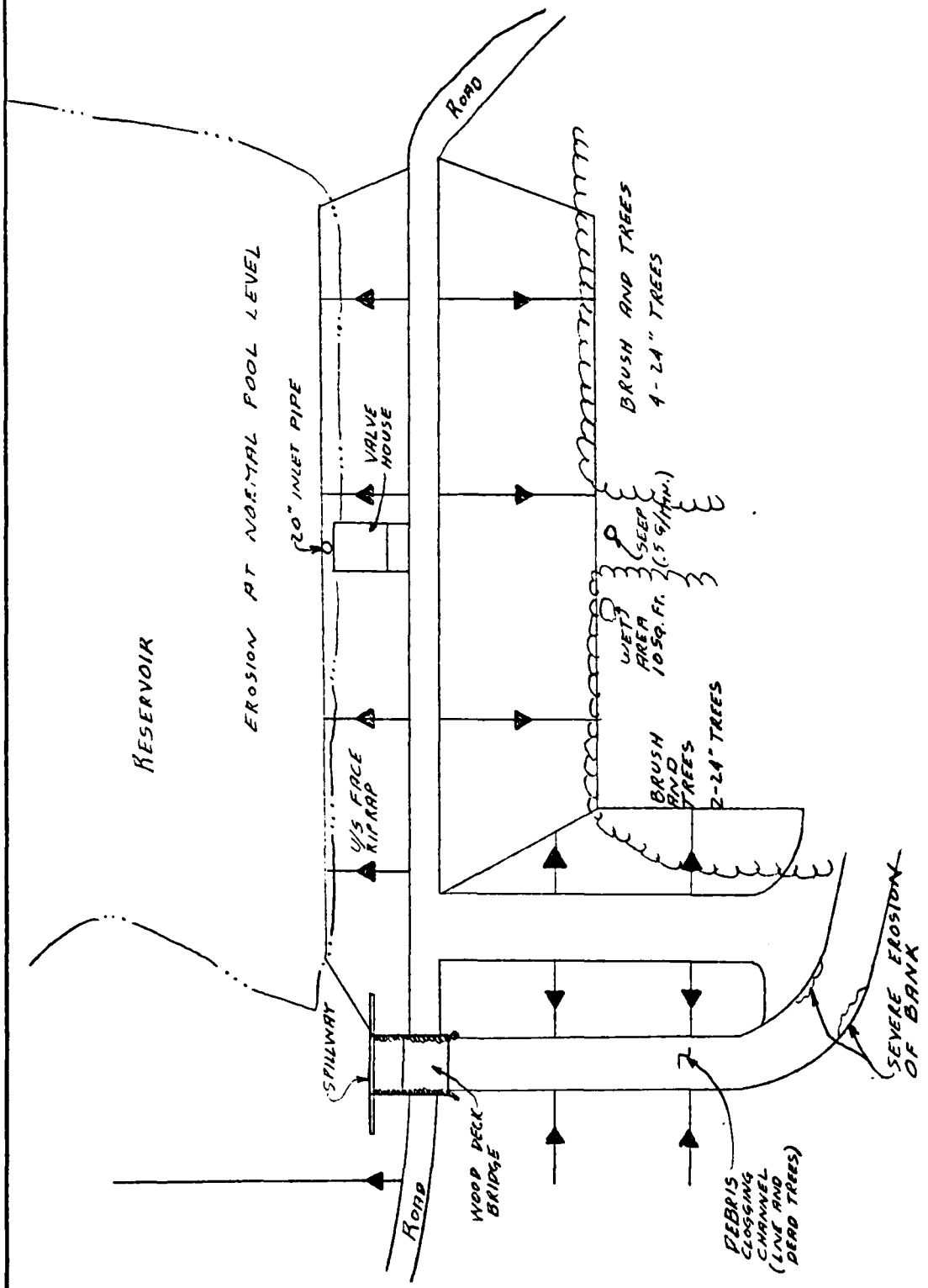
WATERSHED MAP
WOODWARD DAM

MICHAEL BAKER, JR., INC.
THE BAKER ENGINEERS

Box 280
Beaver, Pa. 15009

Subject WOODWARD DAM S.O. No.
FIELD SKETCH Sheet No. of
Drawing No.
Computed by Checked by Date

PLATE 1a

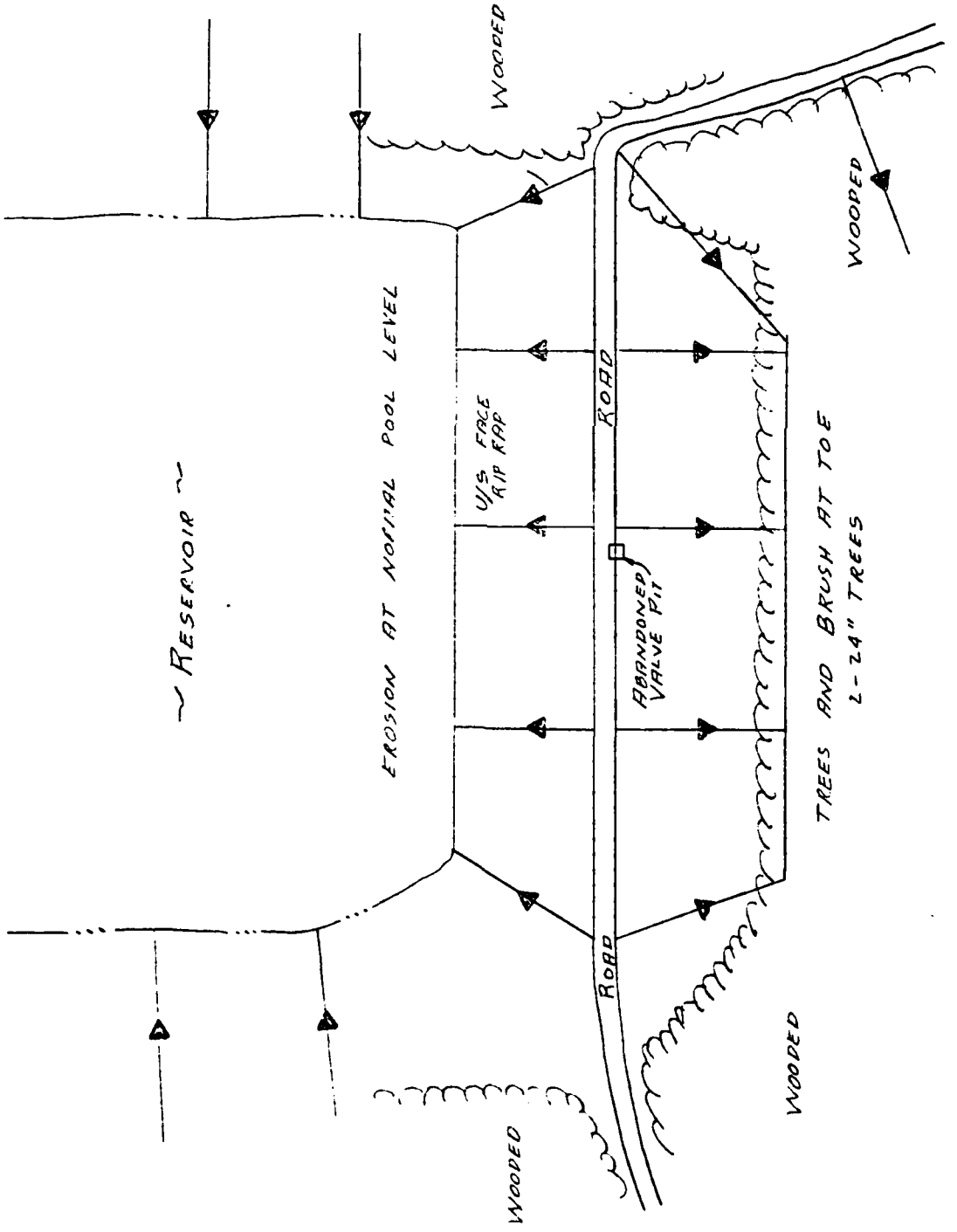


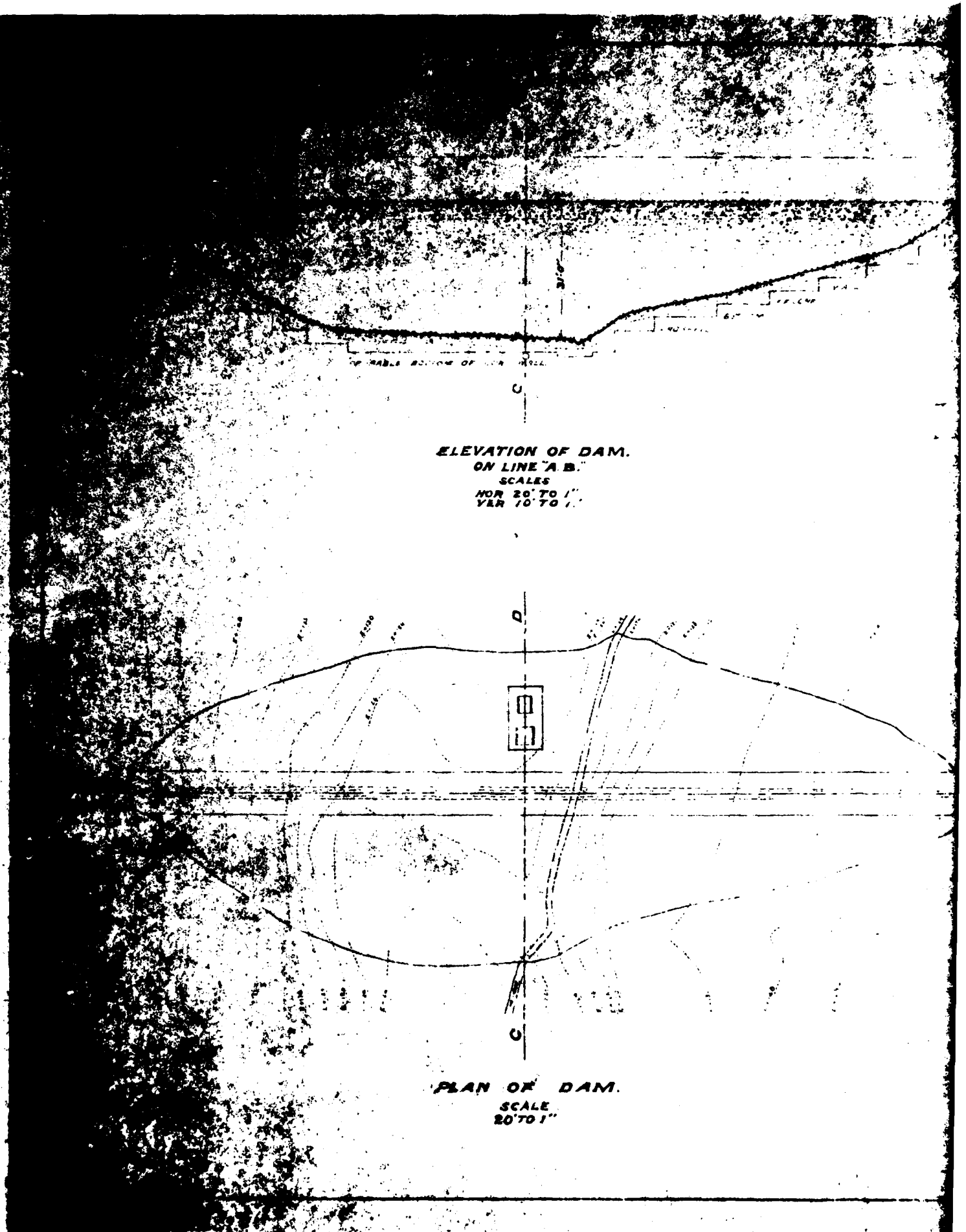
MICHAEL BAKER, JR., INC.
THE BAKER ENGINEERS

Box 280
Beaver, Pa. 15009

Subject GREENLEAF DAM S.O. No.
FIELD SKETCH Sheet No. of
Drawing No.
Computed by Checked by Date

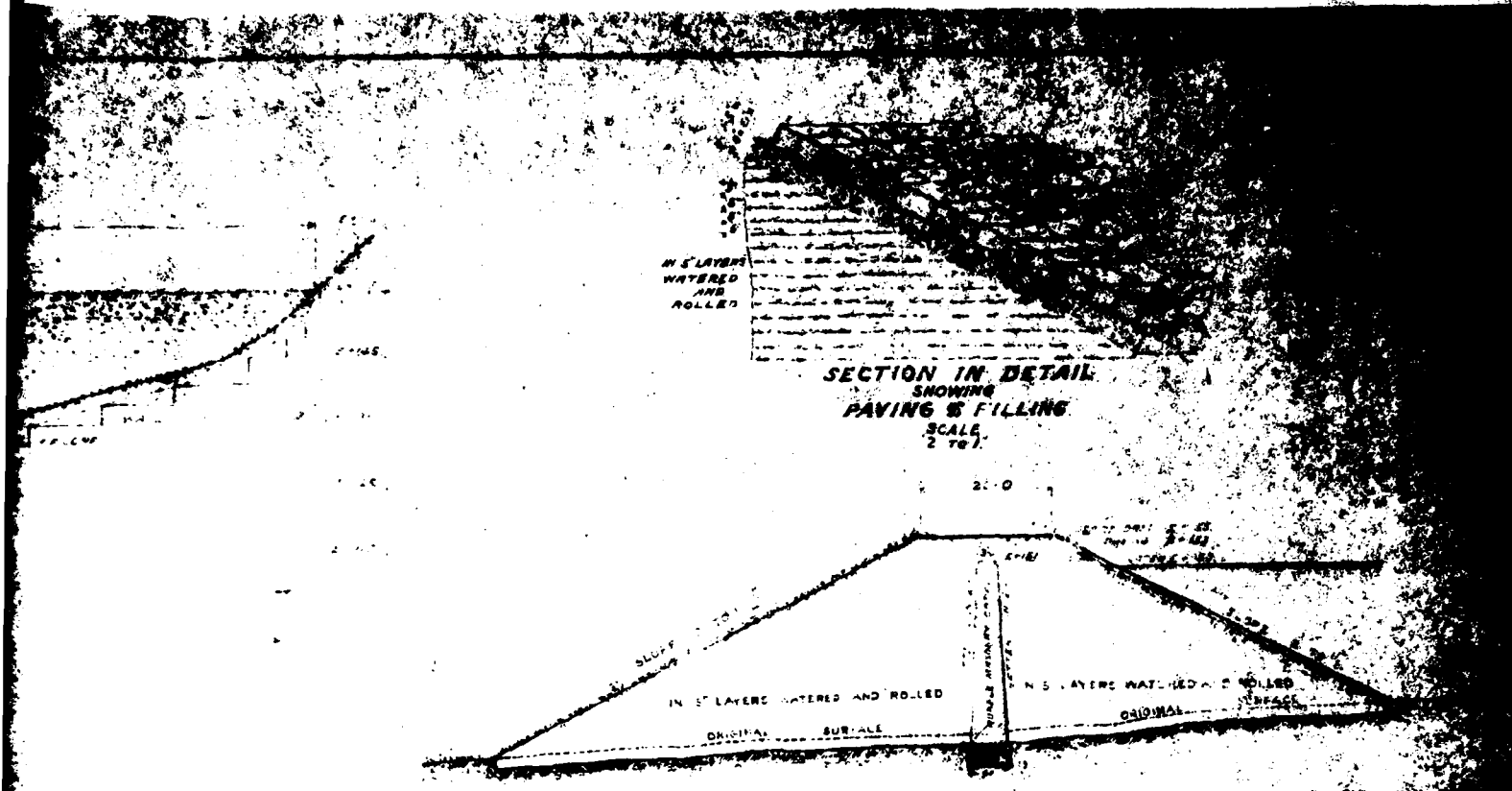
PLATE 16





ELEVATION OF DAM.
ON LINE "A B."
SCALES
HOR 20' TO 1".
VER 10' TO 1".

PLAN OF DAM.
SCALE
20' TO 1"



SECTION OF EARTH DAM
RUBBLE MASONRY CORE
ON LINE C.D.
SCALE.
HORIZ VER.
10 TO 1"

WEST END.
B

BOARD OF WATER COMMISSIONERS
MIDDLETOWN
N.Y.

WOODWARD DAM.

CONSULTING ENGINEER
JAN 1961.

PLATE 2

RESIDENT ENGINEER.

2


Swampy

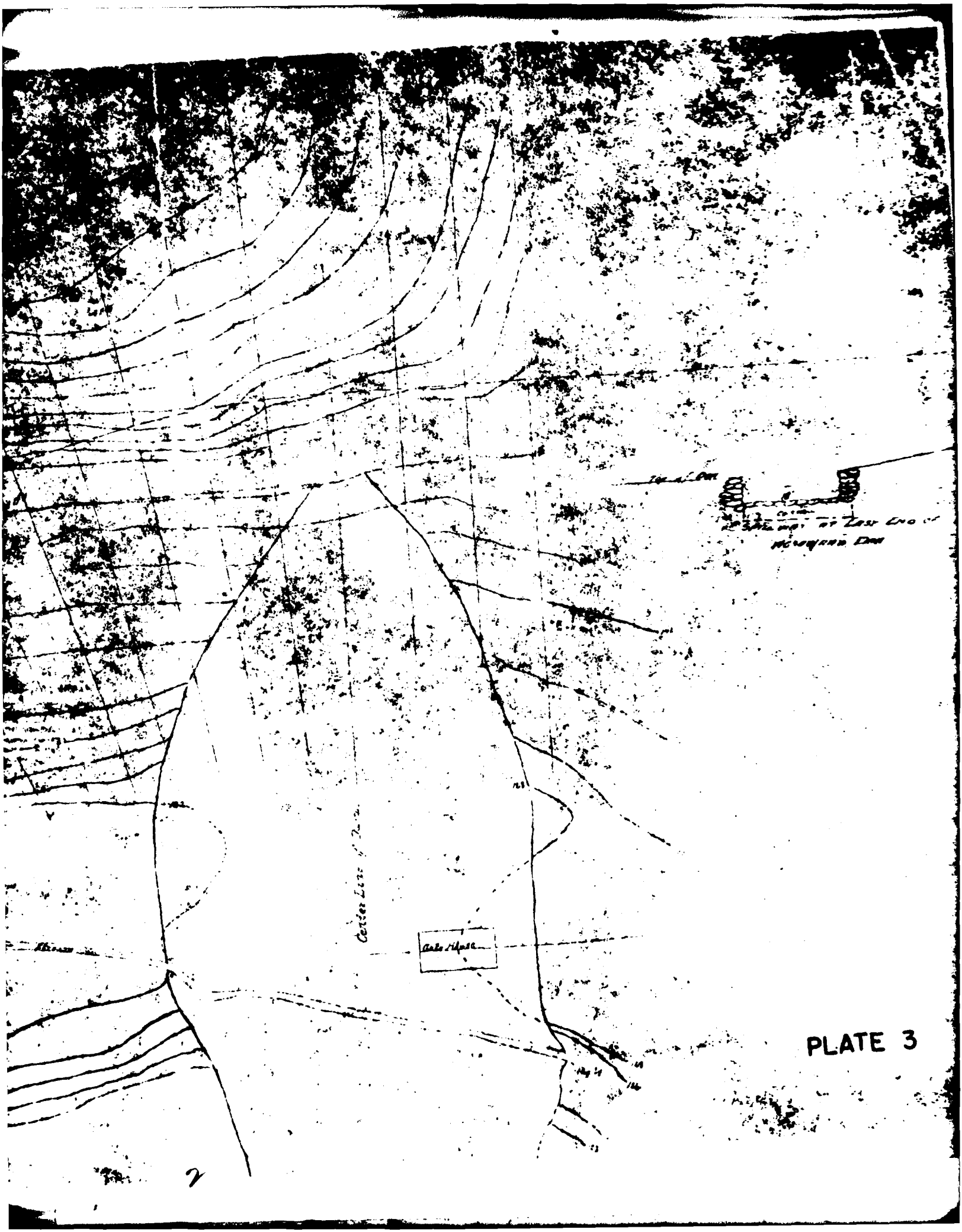
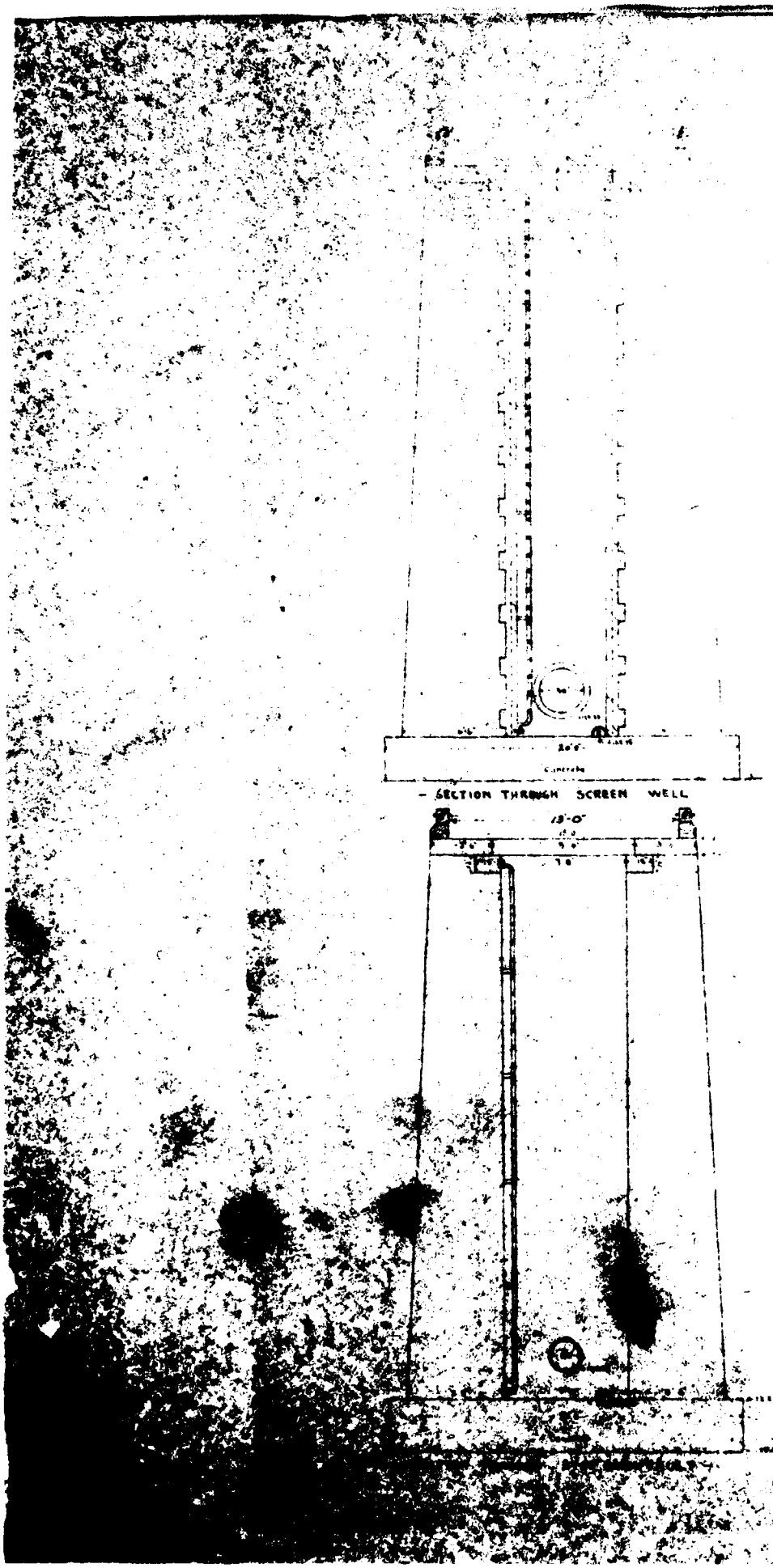
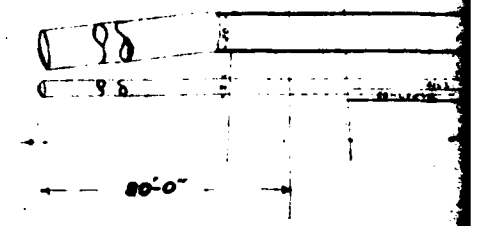
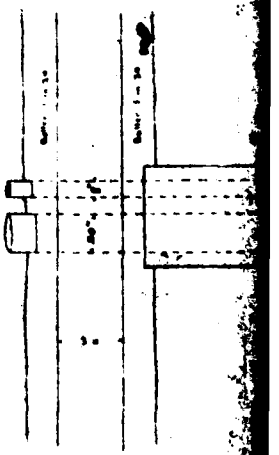


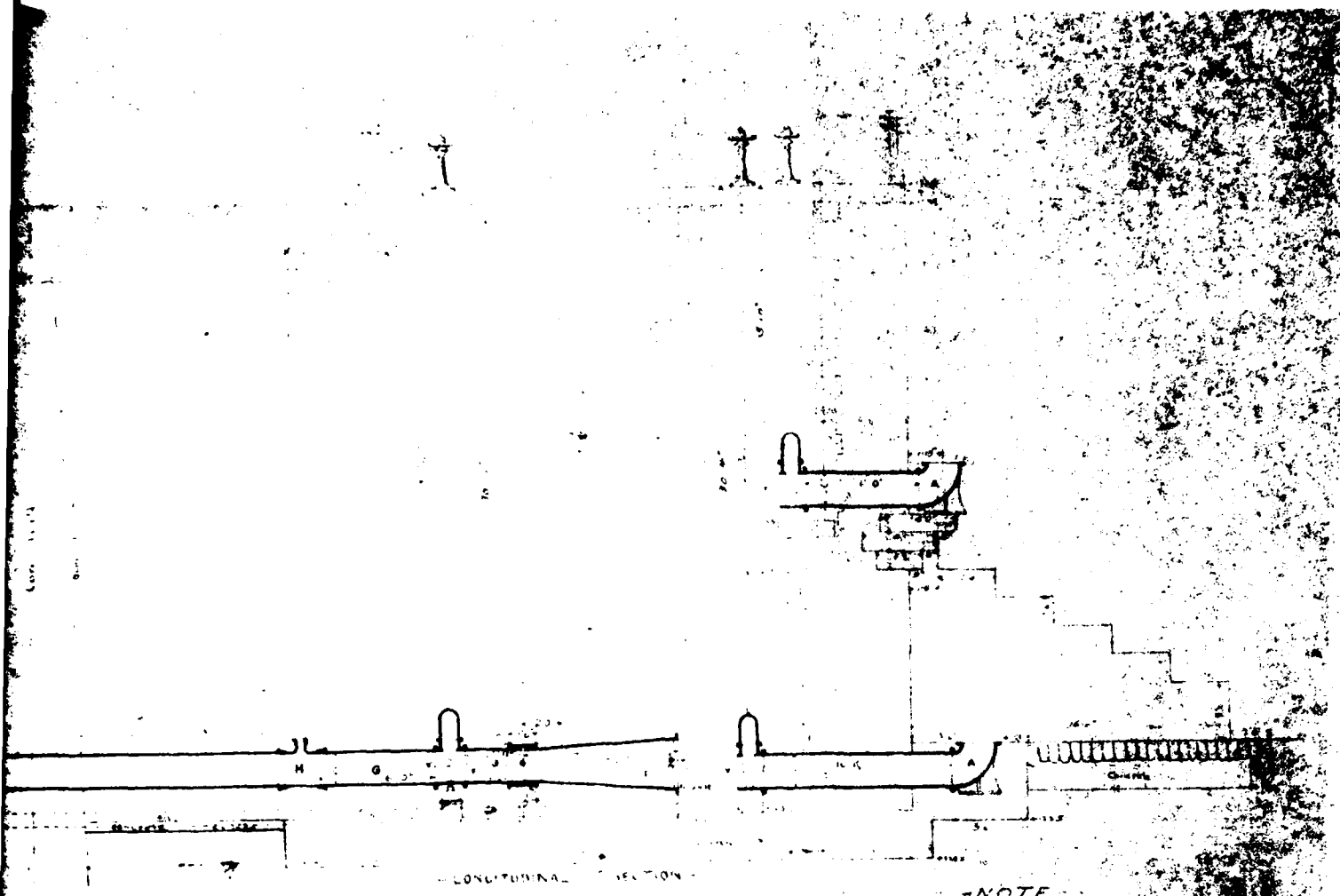
PLATE 3





NOTE - THE 8 INCH AND 20 INCH PIPES ARE TO BE LAID BY THE CONTRACTOR THROUGH THE EMBANKMENT A DISTANCE OF 80 FEET FROM THE CENTRE OF THE CORE WALL.



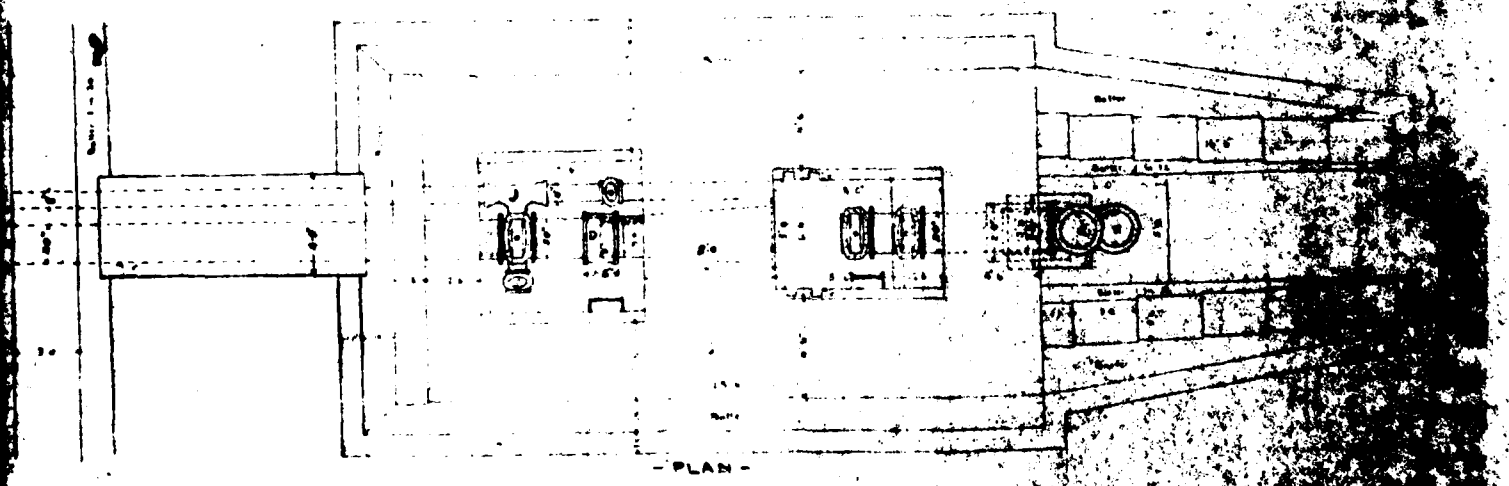


BOARD OF WATER COMMISSIONERS
MIDDLETOWN, N.Y.

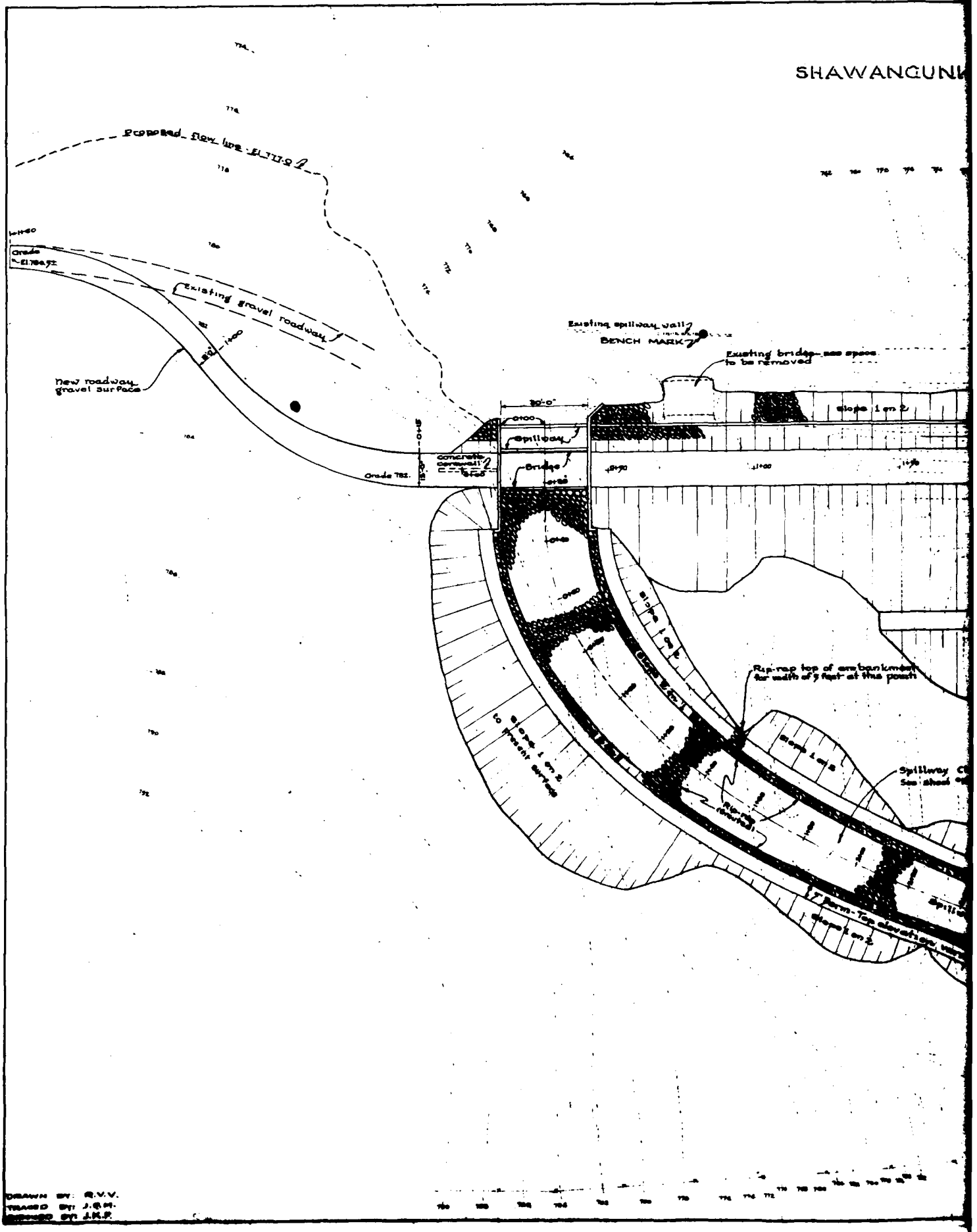
WOODWARD DAM

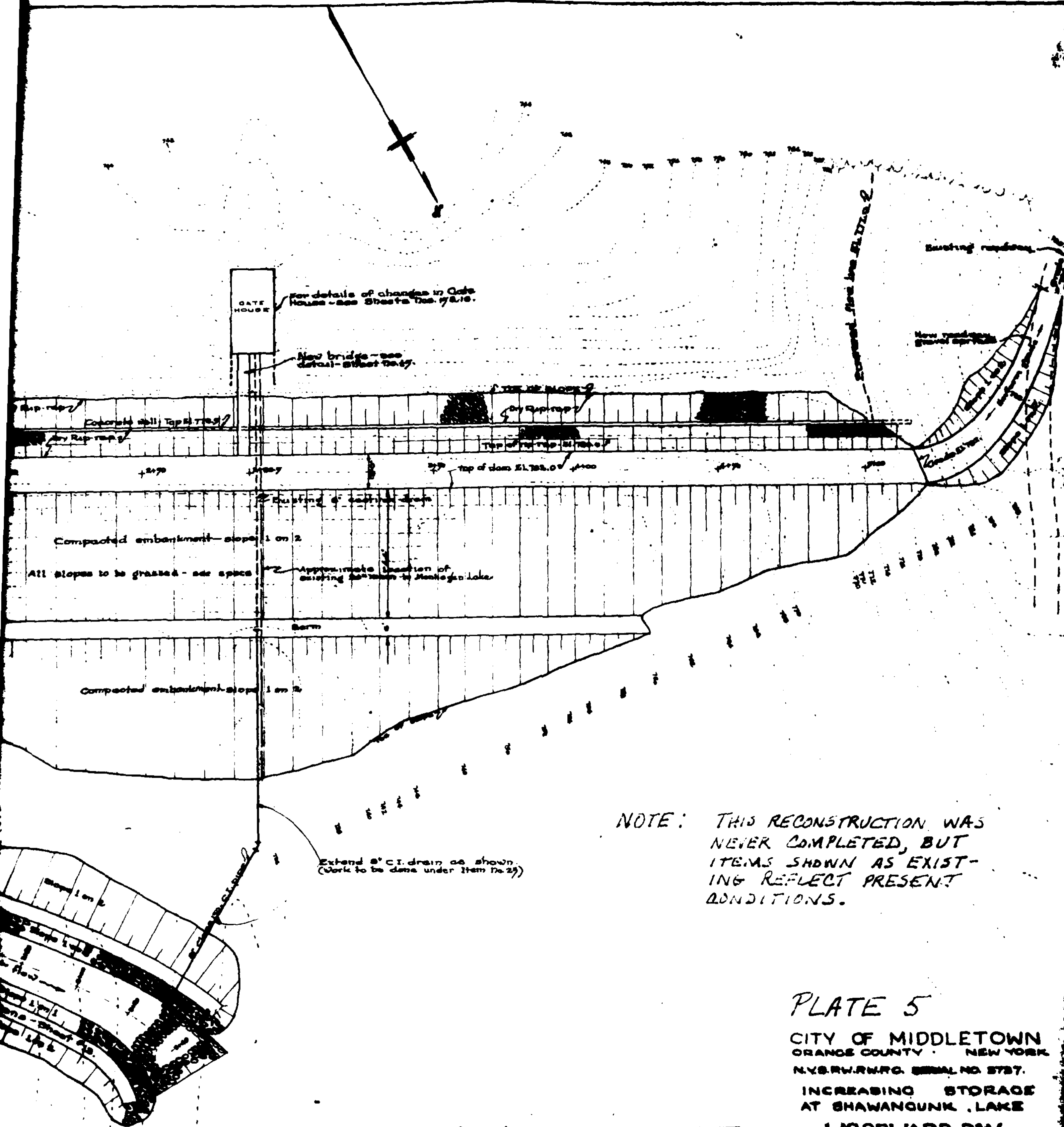
Resident Engineer

-NOTE-



-PLAN-


SHAWANGUNK
Proposed flow line El 777.9
Existing gravel roadway
New roadway gravel surface
Grade El 784.92
Grade 782.
Existing spillway wall
BENCH MARK
Existing bridge see space to be removed
30'-0"
Spillway
Bridge
Concrete Cutwall
Slope 1 on 2
Slope 1 on 2
Slope 1 on 2
to present surface
Rip-rap top of embankment for width of 5 feet at this point
Slope 1 on 2
Rip-rap (typical)
Spillway C
Slope 1 on 2
DRAWN BY: R.V.V.
TRACED BY: J.R.M.
DESIGNED BY: J.K.P.



NOTE: THIS RECONSTRUCTION WAS NEVER COMPLETED, BUT ITEMS SHOWN AS EXISTING REFLECT PRESENT CONDITIONS.

PLATE 5

CITY OF MIDDLETOWN
ORANGE COUNTY · NEW YORK

INCREASING STORAGE
AT SHAWANGUNK LAKE

WOODWARD DAM
PLAN

ALBANY, N.Y.

REVISED NOV. 5, 1947.

Approved: ______
N.Y. State Dept. of Public Works

Approved: ______
N.Y.S. Post-War Public Works Planning Commission
Chairman ______

NOTE: Elevation shown based on Bench Mark - west end of spillway notch - Elevation 787.01

APPENDIX F

BACKGROUND DOCUMENTS

RB	CTY	YR AP.	DAM NO.	INS. DATE	USE	TYPE
01	36	25	542	18/04/74	003	

AS BUILT INSPECTION

1	Location of Sp'way and outlet	1	Elevations
1	Size of Sp'way and Outlet	1	Geometry of Non-overflow section

GENERAL CONDITION OF NON-OVERFLOW SECTION

1					
1	Settlement	1	Cracks	1	Deflections
1	Joints	1	Surface of Concrete	1	Leakage
1	Undermining	1	Settlement of Embankment	1	Crest of Dam
1	Downstream Slope	1	Upstream Slope	1	Toe of Slope

GENERAL COND. OF SP'WAY AND OUTLET WORKS

1					
1	Auxiliary Spillway	1	Service or Concrete Sp'way	1	Stilling Basin
1	Joints	1	Surface of Concrete	1	Spillway Toe
1	Mechanical Equipment	1	Plunge Pool	1	Drain

1	Maintenance	3	Hazard Class
3	Evaluation	JS	Inspector

COMMENTS:

good condition

3-28-24-1000 (6-4905)

STATE OF NEW YORK
DEPARTMENT OF
State Engineer and Surveyor
ALBANY

Received July 14 - 1925 Dam No. 562 Lower Hudson Watershed
Disposition Approved July 23 - 1925 Serial No. 633
Foundation inspected
Structure inspected

Application for the ~~Construction of~~ Reconstruction of a Dam

Application is hereby made to the State Engineer, Albany, N. Y., in compliance with the provisions of Chapter LXV of the Consolidated Laws and Chapter 647, Laws of 1911, Section 22 as amended, for the approval of specifications and detailed drawings, marked Woodward Dam on the Shawangunk Reservoir raising same 2½ ft. herewith submitted for the { ~~construction~~ / reconstruction } of a dam located as stated below. All provisions of law will be complied with in the erection of the proposed dam. It is intended to complete the work covered by the application about Nov 15 1925 (Date)

1. The dam will be on Shawangunk Reservoir flowing into in the town of Mt. Hope, County of Orange and
-- (Give exact distance and direction from a well-know bridge, dam, village main cross-roads or mouth of a stream)
2. The name and address of the owner is City of Middletown, N.Y.
3. The dam will be used for Storage Reservoir
4. Will any part of the dam be built upon or its pond flood any State lands? No
5. The watershed at the proposed dam draining into the pond to be formed thereby is 8 square miles.
6. The proposed dam will have a pond area at the spillcrest elevation of 101 acres and will impound 20,000,000 cubic feet of water.
7. The lowest part of the natural shore of the pond is 15 feet vertically above the spillcrest, and everywhere else the shore will be at least 20-25 feet above the spillcrest.
8. The maximum known flow of the stream at the dam site was cubic feet per second on (Date)
9. State if any damage to life or to any buildings, roads or other property could be caused by any possible failure of the proposed dam No
10. The natural material of the bed on which the proposed dam will rest is (clay, sand, gravel, boulders, granite, shale, slate, limestone, etc.)

11. The material of the right bank, in the direction with the current, is.....; at the spillcrest elevation this material has a top slope of .....inches vertical to a foot horizontal on the center line of the dam, a vertical thickness at this elevation of.....feet, and the top surface extends for a vertical height of ..... feet above the spillcrest.

12. The material of the left bank is.....; has a top slope of.....inches to a foot horizontal, a thickness of.....feet, and a height of.....feet.

13 State the character of the bed and the banks in respect to the hardness, perviousness, water bearing, effect of exposure to air and to water, uniformity, etc.....

14. If the bed is in layers, are the layers horizontal or inclined?..... If inclined what is the direction of the horizontal outcropping relative to the axis of the main dam and the inclination and direction of the layers in a plane perpendicular to the horizontal outcropping.....

15. What is the thickness of the layers?.....

16. Are there any porous seams or fissures?.....No.....

17. WASTES. The spillway of the above proposed dam will be.....16.....feet long in the clear; the waters will be held at the right end by a.....the top of which will be .....6½.....feet above the spillcrest, and have a top width of.....feet; and at the left end by a..... the top of which will be.....feet above the spillcrest, and have a top width of.....feet.

18. There will be also for flood discharge a pipe.....inches inside diameter and the bottom will be..... feet below the spillcrest, a sluice or gate.....feet wide in the clear by .....feet high, and the bottom will be.....feet below the spillcrest.

19. APRON. Below the proposed dam there will be an apron built of..... feet long across the stream, ...feet wide and.....feet thick. The downstream side of the apron will have a thickness of.....feet for a width of.....feet.

20. PLANS. Each application for a permit of a dam over 12 feet in height must be accompanied by a location map and complete working drawings in triplicate of the proposed structure, one set of which will be returned if they are approved. Each drawing should have a title giving the parts shown, the name of the town and county in which the dam site is located, and the name of the owner and of the engineer.

The location map (U. S. Geological Quadrangle or other map) should show the exact location of the proposed dam; of buildings below the dam which might be damaged by any failure of the dam; of roads adjacent to or crossing the stream below the dam, giving the lowest elevation of the roadway above the stream bed and giving the shape,

The above information is correct to the best of my knowledge and belief.

Middletown N.Y.
(Address of signer)

July 13 1925
(Date)

John Machon
Comr Public Works
(A person signing for owner should indicate his title or authority)

July 24, 1925.

Dam 562, L. Hudson.
Middletown.

Commissioner of Public Works,
Middletown,
N. Y.

Dear Sir:

Application having been duly made to the State Engineer, you are hereby given permission up to November 30, 1925, in so far as the matter involves the jurisdiction conferred upon this office by chapter 82 of the laws of 1923, to reconstruct the Woodward dam at the northeast end of the Shawangunk Lake, designated on the records of this Department as dam No. 562, Lower Hudson watershed, by raising the embankment 2.5 ft. according to the two prints in triplicate submitted therefor, under the following conditions:

1. That the slopes of the embankment if made steeper than 1 vertical to 2-1/2 horizontal on the upstream side, be well laid in Portland cement.

2. That the spillway be laid up in cement mortar and have a cutoff of 3 ft. deep into the bed and into the banks.

3. That the Lamson dam at the southwest end of Shawangunk Lake, and designated on the records of this Department as dam No. 559, Lower Hudson watershed, be raised to the same elevation as the Woodward dam, be paved on the upstream slope and have the same depth, elevation, top width and slopes as required for the Woodward dam.

4. That the embankments and wall of the channel be constructed by paving wherever they may be subject to any wave or current erosive action.

5. That this Department be notified when the work is started.

This approval shall not be deemed to authorize any invasion of property rights, either public or private, in carrying out the above work; nor to create any claim or demand against the State of New York, nor to authorize the flooding or use of State lands; nor to acquiesce in the flooding or use of such lands.

No. 2.

Commr. Public Wks, Middletown July 23, 1926.

On July 16th there were sent to you report blanks to be filled out, one for each of the other dams besides the Kinch dam and the Lamson, Greenleaf and Woodward dams on the Shawangunk Lake,- these include the two dams on Highland Lake, the two dams on Monhagen Lake and perhaps others. These report blanks were returned partially filled out for the Shawangunk Lake dams. We enclose additional blanks for the dams on Highland and Monhagen Lakes.

Anknowledgment is requested of the receipt of this letter and of the prints.

Yours very truly,

Roy G. Finch,
State Engineer.

By
Assistant Deputy.

AHMcK/ECH